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A DYNAMIC MONTE CARLO SIMULATION OF A REPAIRABLE INVENTORY SYSTEM

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A DYNAMIC MONTE CARLO SIMULATION OF A REPAIRABLE INVENTORY SYSTEM

by

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B.S., United States Naval Academy, 1956

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partial fulfillment of the
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Instructor in Charge

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ABSTRACT

The simulation presented here attempts to provide a testing device to be used in evaluating repairable inventory decision rules. The complexity of the repairable inventory problem prevents mathematical analysis, and trial-and-error solutions are too costly and time-consuming: hence the systems simulation approach.

The system is a general one and depicts the author's opinion of what the average system design might be. Theoretical evaluations are possible, and several are presented.

ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

Inventory management is a topic of considerable and wide-spread interest. Broadly speaking, the inventory management problem is one of maintaining, for a given financial investment, an adequate supply of something in order to meet an expected distribution or pattern of demand. In answering the basic question of how much to order and when to order it, inventory managers are faced with many pressures and conflicting criteria presented by outside persons having varied interests in the inventory management operations. For instance, the accounting department will want to make sure that the inventory is carried and procured at the least cost. The production department, on the other hand, will insist that enough material be procured so that they will never run short when meeting a production schedule. To summarize, then, the inventory manager is told, "Don't run out of, but don't be overstocked with material."

If the inventory manager were certain of the demand to be expected and its exact arrival pattern, and if he knew exactly when material would be delivered from procurement, the solution to the inventory management problem would be an analytical one and could easily be solved, allowing performance to be judged with certainty. This is not the case, however, as demand is random and procurement delivery times and material delivery schedules are subject to variations. It becomes apparent, therefore, that the inventory management problem under uncertain conditions is one of minimizing cost while maintaining a desired level of effectiveness. In

order to overcome the problems of uncertainty, many people have been working on new procedures for forecasting demand, determining inventory levels, and computing economical order quantities by taking into account such factors as risk, holding cost, interest rates and shortage costs. The inventory problem has become very complex and sophisticated, and does not readily lend itself to an analytical solution. Systems simulation has become a very useful tool in this class of problems, wherein operating rules, policies, procedures and other elements that control inventory are influenced by uncertainty in demands, lead times, costs, and other elements affecting inventory levels.[1] By the use of simulation we are allowed to study the inventory system as a function of time.

Repair Problem

Inventory management problems can be classified into many categories, but the most general division is between consumable and repairable item management. A consumable item is an item the usefulness of which is completely expended subsequent to its initial issue, and which will never be capable of being reissued. A repairable, on the other hand, is an item that, because of its high cost, complexity, or other considerations, could be returned to a central point for repair and subsequent reissue. With the recent advances in technology and the new modular or "Black Box" types of systems, the number of items worthy of repairable-item management has increased rapidly. It has been recognized for many years that large items such as airplane engines should be managed as repairables, but now it is recognized that many items of lesser cost and

size can be effectively managed as repairables, with significant savings to the overall inventory costs. The major changes in the items and their environment are the complexity and high cost of the items. When a complex item now fails, the level of competence of personnel and the sophisticated test equipment required for repair preclude repair in the field. This, coupled with the high procurement costs when the items are managed as consumables, dictates the need to examine the overall costs and the possibility of returning the items for repair and reissue. The following is a list of repair parts that might be considered to fall in this category.

1. Electronic Module - used in the memory circuits of a large mass-produced computer.
2. Magnetic Memory Drum - used in the fire control system of a Fleet Ballistic Missile Submarine.
3. Gear Train Assembly - used in the inertial navigation system in a Fleet Ballistic Missile Submarine.
4. Fuel Cell or Carburetor - used in high performance aircraft.
5. Power Recovery Turbine - used in propeller-driven aircraft.
6. Mass Flowmeters - used in the various refineries of an oil company.
7. Test Equipment - used almost anywhere; requires very sensitive realignment.

The above items have several things in common, such as high cost, special tools needed for repair, and a high level of technical understanding required in the actual repair and rehabilitation of the part. It is assumed that, because of the high cost of maintaining skilled technicians together with the highly sophisticated test equipment, field repair is not practical, and that central repair of these parts would in fact be economical.

As was previously mentioned, the inventory management problem is surrounded by uncertainty. It would be useful here to mention the major sources of uncertainty in consumable item-management.[2]

1. Variability of demand.
2. Variability of procurement delivery schedules.
3. Variability of delivery schedules to Subsupply points within the total supply system.

When considering the repairable item-management problem, the same uncertainties surrounding the consumable item are present; but in addition, the following must be considered.

1. Variability of an item being returned for repair. When a new item is issued, the item it is to replace could have failed in such a manner as to make it obviously incapable of repair. The possibility of loss also exists. Therefore, not all issues will generate an item that will return to await possible induction into repair (carcass return rate).
2. Variability of an item inducted into repair but not surviving. When an item is in the actual repair facility, it is possible that the cost of repair will exceed the limitation placed by the inventory manager. In this case, the inventory manager will be notified and the item discarded (carcass survival rate).
3. Variability of actual repair completion time.
4. Variability of shipment time:
    a) From failure point to Main Supply point for subsequent repair.

b) From Main Supply to Repair Facility.

c) From Repair Facility to Main Supply.

It can be seen from the above that the primary difference between the consumable-and repairable-item management problem is that in consumable management, all assets that are to be issued must come from procurement. However, in the repairable problem, procurement is a combination of obtaining unused assets and regenerating previously-used assets. The inventory problem for the consumable reduces to:

1. Prediction of how much will be demanded.
2. Decision as to how much to buy.
3. Decision as to when to buy.

For the repairable, the above are included, but further answers are needed to the following problems:

1. Prediction as to how much can be regenerated.
2. Decision as to how much to repair.
3. Decision as to when to repair.

When determining whether an item should be managed as a repairable, one must consider the extra costs associated with the repair program vs. the savings in new procurement costs for a given measure of performance. It is obvious that less material will be procured, thus producing savings. Transportation costs for the possible induction and return of material to and from repair, plus actual repair costs, offset the procurement savings. Therefore a balance must be obtained and guide lines established so that the repairing activity will know the limitation on repair costs. This limitation is normally expressed as a percentage of the cost of a new item.

The Scope and Method of Simulation System

Many authors use different terminology in defining systems and models. The simulation to be developed in this thesis can be classified and described most simply in general terms by using the scheme described by Mssrs. McMillan and Gonzalez in their book "Systems Analysis, A Computer Approach to Decision Models."[3]

Basis for System Classification:

1. Natural or Man-made. The simulation of a supply network is considered to be man-made, even though the environment in which it operates will contain natural systems.
2. Open or Closed. The use of the model developed here will be to test the internal decision rules, and the results will represent their effect: therefore, the system will be considered closed.
3. Adaptive or not. The present model will be adaptive, as it will adjust demand forecasts based on actually experienced demand.
4. Stable or Unstable. The very nature of the uncertainty of demands, times, and regeneration make the period uncertain, but over long periods of time the system stabilizes and the values stay within acceptable limits.
5. Steady-State, Transient or Exploding. The developed model will change values with time, but the results -- such as average costs per period and effectiveness -- will approach steady state as the number of periods increases without bounds.

Models are classified in part by the nature or physical form of the model. In this sense, three basic types of models are the physical,

schematic and mathematical. A physical model is, for example, an analog computer simulating a hydraulic system or an oil refinery. A schematic model could be a pictorial representation of a system; an example would be the flow charts that were constructed when preparing the simulation in this thesis. A mathematical model consists of a set of equations whose solution explains or predicts changes in the state of the system. The mathematical model used in the simulation will be the decision rules for repairable parts that were recently used at the Ships Parts Control Center, Mechanicsburg, Pennsylvania.

Models are further classified as to whether they are probabilistic or deterministic. The previously mentioned inventory system is to a great extent dependent on effects that are random; hence the simulation will definitely be classified as probabilistic.

After the decision rules for repairable parts have been reduced to a mathematical model, it is necessary to develop a method for analyzing the effects when and if the model is employed to study policy. The interactions between the many rules that constitute repairable-item management are so complex that without a simulation of the system, it is almost impossible to determine what the overall effect will be of any rule or change in a rule. A simulation makes it possible first to study alternatives to select the best method for a particular situation, and then to demonstrate that the model does cope satisfactorily with all conceivable contingencies.

A simulation is here defined as a dynamic representation of the actual environment. As the calculations for a probabilistic simulation are very time-consuming, it is mandatory that a computer be used. The use of a

computer allows one to trace the time paths of the variables and generate statistics for later analysis.

Figure 1 is a generalized schematic of the system simulation. It should be noted that the operator or executive control is outside the normal running loop, so the system is said to be closed.

The model will be run for enough trials that the values at the end of the simulation will closely approach the statistical expectation if the set of decision rules and procedures depicted by the simulation were actually put in use. A simple analogy might be the flipping of a coin. After ten trials it would be very possible to have 8 heads and 2 tails; yet if the coin were flipped 100 times the number of heads would approach the known expectation of 50 percent heads. Caution must be exercised, because the model or simulator is not a short-run predictive device. It is capable of showing what should happen in the long run, or showing that one rule box should do better than another, but any conclusions apply only to long-term average behavior, not to short-term behavior.

It must be emphasized that a model of this nature would need to be developed for each individual system that was to be examined. It is hoped that the choice of a general repair system, to be described in Chapter II, will make it useful to others in testing theoretical questions concerning this model.

Language Selection[4]

It will be necessary, when preparing the simulation model for computer use, to give instructions for the computer. Programs may be written

GENERALIZED SYSTEM FLOWCHART

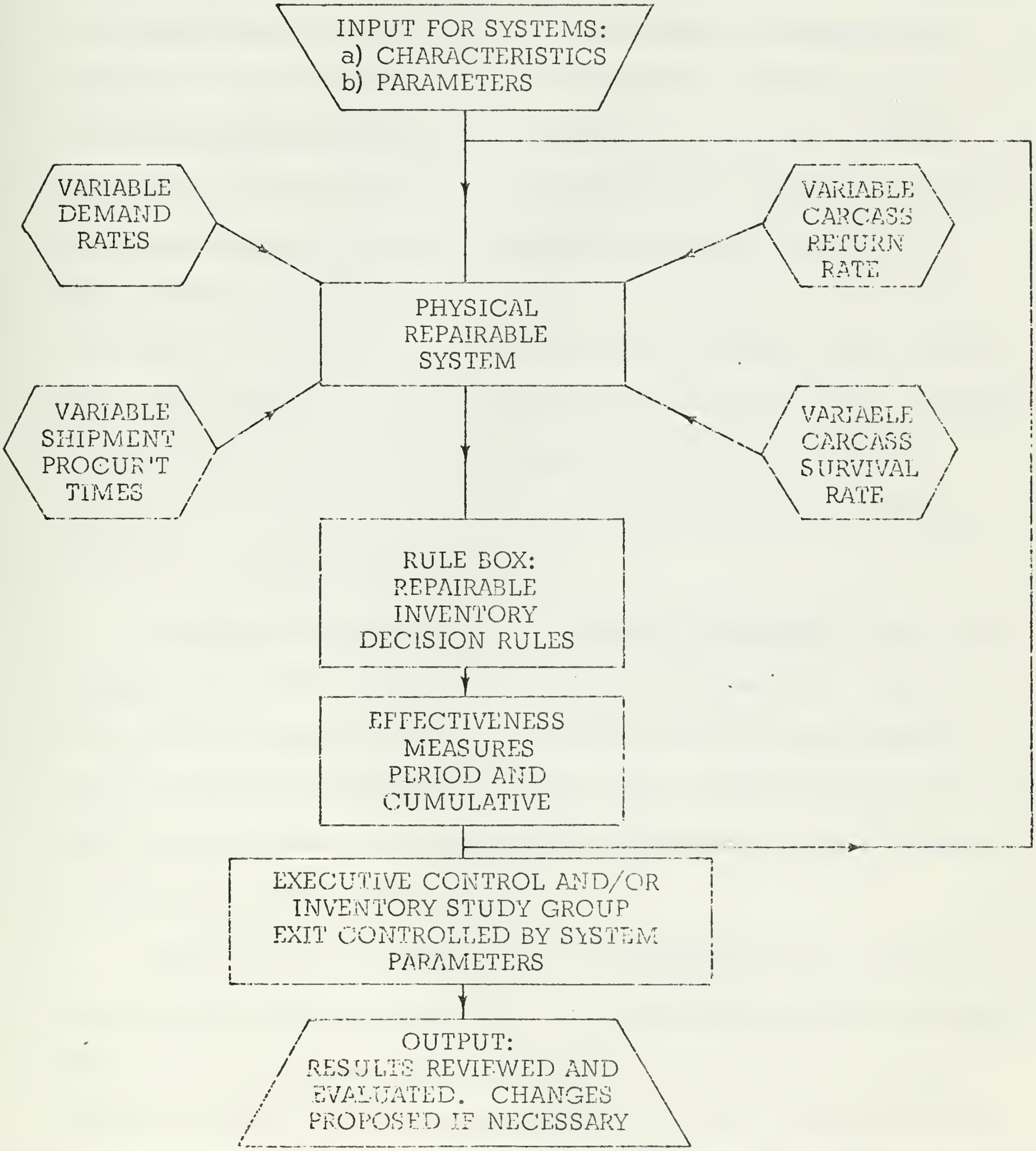
INPUT FOR SYSTEMS:
a) CHARACTERISTICS
b) PARAMETERS
VARIABLE DEMAND RATES
VARIABLE CARCASS RETURN RATE
PHYSICAL REPAIRABLE SYSTEM
VARIABLE SHIPMENT PROCUR'T TIMES
VARIABLE CARCASS SURVIVAL RATE
RULE BOX: REPAIRABLE INVENTORY DECISION RULES
EFFECTIVENESS MEASURES PERIOD AND CUMULATIVE
EXECUTIVE CONTROL AND/OR INVENTORY STUDY GROUP EXIT CONTROLLED BY SYSTEM PARAMETERS
OUTPUT: RESULTS REVIEWED AND EVALUATED. CHANGES PROPOSED IF NECESSARY

Figure 1

in any number of "languages," but the computer itself understands only one language: machine language. Developing a thorough knowledge of "machine language" requires a great deal of study, and constructing programs is very tedious and slow. To bridge this knowledge gap and to make the computer more readily available to more users, additional languages have been developed to help individuals of varied backgrounds use a computer more efficiently. When programming is done in any of these special languages other than machine language, it must first be "translated," by means of a special intermediary program called a compiler, into machine language. It is therefore necessary, before selecting a specific language to be used, to determine the compilers that are available for the computer to be utilized. The following is a summary of the more commonly-used languages.

FORTRAN (An abbreviation for FORmula TRANslation) is the most universally used language for which compilers are available. Fortran, being nearly a universal language, is ideally suited to model building and is a good basic language from which to learn other computer languages when the need arises. A Fortran program consists of a number of statements or instructions to the computer.

GPSS (General Purpose Systems Simulator) is another programming language that has been designed specifically for queueing systems. GPSS has a logic structure that permits it to serve, in a sense, as a shorthand version of many Fortran statements grouped together for usage within a queueing problem. A single statement within the GPSS language could very easily represent as many as 10 individual operations that would

be needed if the system were constructed using the Fortran language. In summary, then, with a GPSS compiler, one could construct very complex queue systems simulations with a very small number of statements.

SIMSCRIPT - Simscript, like GPSS, is also another type of language that could be considered a type of shorthand. Here again, many Fortran data manipulations can be called into operation by only one or a few Simscript statements.

Both Simscript and GPSS contain significant advantages, both in simplicity and flexibility, when utilized in developing a complicated simulation model. These two systems would be the normal choices in developing a complex computer simulation model: however, compilers for these two languages are not available at the computation center used by this author. Therefore the Fortran language has been selected for use.

CHAPTER II

PHYSICAL SYSTEM TO BE SIMULATED

Philosophy of System Selection

Because of the added transportation costs and repair costs of all items to be included in repairable-item management, it follows that one criterion for selection will be high unit cost. In addition, as repair contracts must be let and contract administration pursued, sufficient volume must be anticipated to make it feasible. To summarize, then, the general criteria for selection of an item for repairable-item management are:

1. Item must be repairable.
2. Specialized repair, other than in the field, must be required.
3. Unit price must at least be one hundred dollars.
4. Regeneration must be at least twenty units per year.

Other items might, of course, be accepted into the repair program, but these will be treated as special cases.

When the criteria are examined it becomes apparent that stocking this type of material at a limited number of stocking points will reduce stock levels, material-in-transit costs, and administrative control costs. This policy could be modified if the operational needs of the customers dictate the need for material in their immediate vicinity.

Access was not readily available to an operating system: therefore, the physical system to be simulated will be a hypothetical one. It will be composed of the following functional locations:

1. Main Supply
2. Subsupply East
3. Subsupply West
4. Repair Facility

The shipment links between these points are variable and are inputs to the model; therefore, the model can be modified to meet various other system configurations. Demand from end-use customers is generated at Main Supply, Subsupply West and Subsupply East. In addition, Main Supply will receive requisitions from Subsupply West and Subsupply East. Figure 2 graphically displays the locations capable of being used in the system. For this simulation, specific locations were selected so that realistic transportation times and costs could be added for additional realism. Subsupply West is at Pearl Harbor, Hawaii, Subsupply East is at London, England, Main Supply is at Norfolk, Virginia, and the Repair Facility is at Long Beach, California.

Physical Characteristics of the System

It is necessary to examine the principal locations in the physical system to gain insight into the operation of the simulation. A short discussion will describe each activity and its responsibilities to the total system.

Subsupply East and Subsupply West

General -- These activities are considered to be field stocking activities. They will maintain stock necessary to support requisitions from customers in the immediate area. The facilities and personnel are limited and are

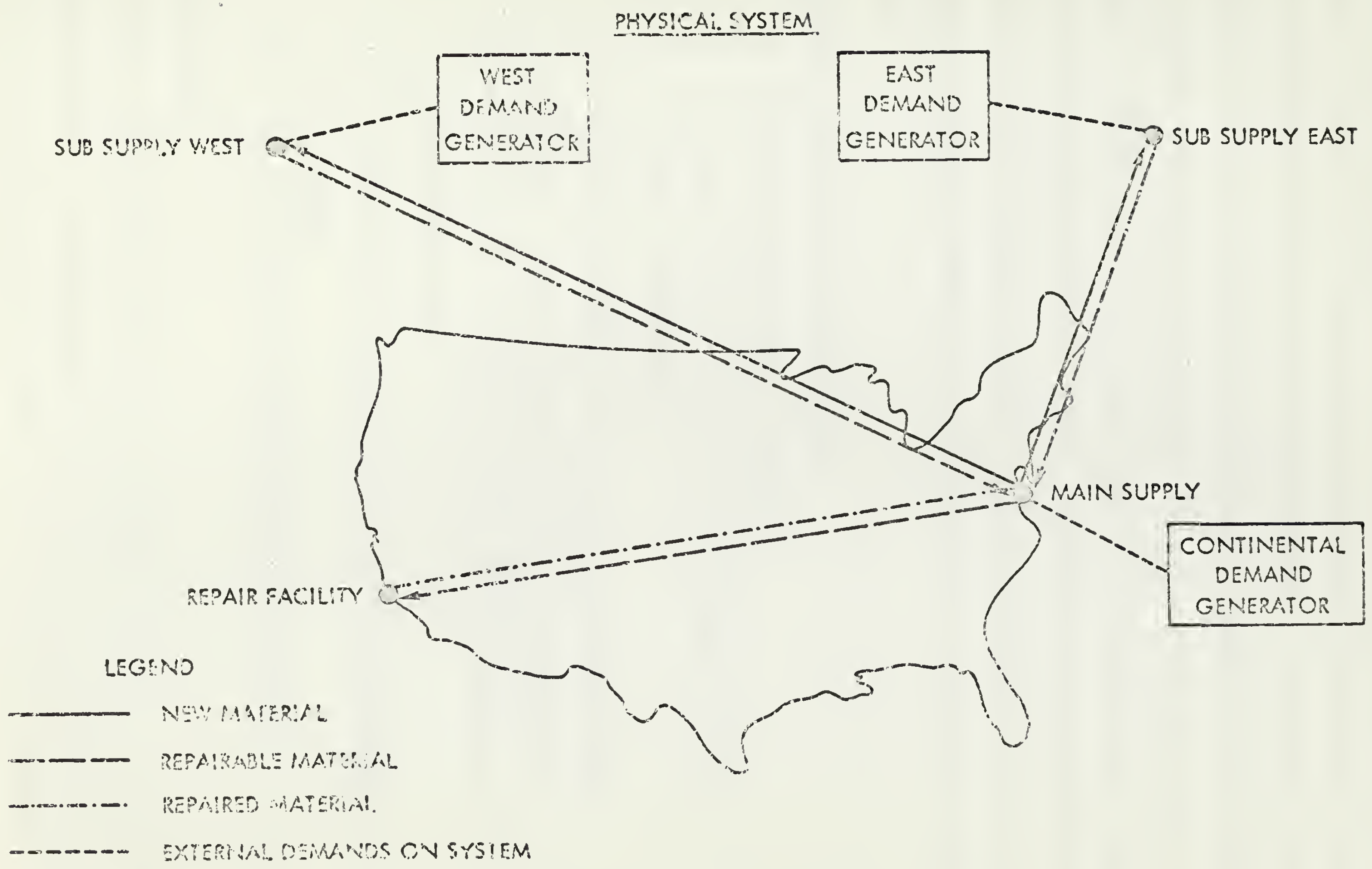
PHYSICAL SYSTEM
WEST DEMAND GENERATOR
EAST DEMAND GENERATOR
SUB SUPPLY WEST
SUB SUPPLY EAST
MAIN SUPPLY
CONTINENTAL DEMAND GENERATOR
REPAIR FACILITY
LEGEND
NEW MATERIAL
REPAIRABLE MATERIAL
REPAIRED MATERIAL
EXTERNAL DEMANDS ON SYSTEM

Figure 2

not capable of sophisticated inventory management. Repair facilities are at a minimum, and items needing repair must be returned to Main Supply for scheduled induction into a repair facility. Forecasting demand occurs at the same time that the forecasts are updated at Main Supply. The method, however, is to generate a two-period moving average. The method of determining requirements is to compare requirements with assets on hand plus dues from Main Supply. If the assets are equal to or less than two months' expected demand, then the deficiency plus one month's expected demand is ordered, and the requisition is forwarded to Main Supply.

Functions Performed by the Subsupplies

1. Receives demand from customers.
2. Maintains current on-hand items available for issue.
3. Maintains backorder file.
4. Requisitions replacement material from Main Supply.
5. Maintains a file of material due from Main Supply.
6. When an item is issued, decides whether carcass will be returned for repair.
7. Generates time-of-arrival of carcass at Main Supply, if it is to be returned.
8. Generates the time of next demand at location.

Main Supply

General - This activity is the central inventory control point for the item being simulated. It stocks material for issue to the Subsupplies and to end-use customers in the immediate area. In addition, it performs the

requirements reviews necessary to maintain levels for satisfactory performance of the entire system.

Functions Performed by the Main Supply

1. Receives demand from local end-use customers.
2. Receives demand from Subsupplies.
3. Maintains current on-hand items available for issue.
4. Maintains current on-hand items of material awaiting repair.
5. Maintains backorder file (first in, first out).
6. Performs requirements review.
7. Orders material from procurement.
8. Generates estimate of the time when any material from procurement will be received in the system.
9. Directs that given material be inducted into Repair Facility.
10. Generates estimate of the time when any material will be received at Repair Facility.
11. Forecasts Main Supply future demand, based on past experience.
12. Maintains file of material due from procurement.
13. Maintains file of material due from repair.
14. When an item is issued to local customers, decides whether carcass will be returned for repair.
15. Receives carcasses from Subsupplies to await induction into repair.
16. Generates time of next demand from local end-use customers.
17. After requirements review, generates time of next review.
18. After demand forecast update, generates time of next demand forecast update.

19. Receives material from procurement and Repair Facility and releases backorders on a first-in, first-out basis, as necessary.

Repair Facility

General - This activity has been selected by Main Supply to repair the item simulated.

Functions Performed by the Repair Facility

1. Receives items to be repaired from Main Supply.
2. Generates time when items to be repaired will depart Repair Facility.
3. At departure time from repair, determines how many carcasses did not survive repair.
4. Generates arrival time of those surviving repair at Main Supply.

System Discipline

It is important to understand the rules under which the system is operating, as they must be included in the simulation. It is possible that some rules may impose adverse effects on the system, but proving this through simulation could be a valuable by-product of this study.

Units Demanded - It is assumed that, because of the high prices of the items in the repairable category, demands from local customers will be for a quantity of one item. After a demand is placed, it remains in the system until an issue is consummated.

Return of Defective Material - Material is not considered for return unless an actual issue takes place. Many times the prime equipment will still be operable, but to a lesser degree of effectiveness.

Priority of Issue - All requisitions are considered to be of the same priority, and issues are made on a "first-come, first-served" basis.

Release of Backorders - All backorders are released on a "first-in, first-out" basis.

Consolidation for Shipment - When operations such as material receipts cause a batch of backorder releases (and consequently the return of many items) at one point in time, shipments will be consolidated.

Requisition Effectiveness - When a requisition is received, it is counted as a demand. If it is completely filled on time, it is counted as an issue. If a requisition is partially filled, then it is considered to be one demand with an issue and another demand with no issue. At the end of the reporting period, the number of issues is divided by the number of demands to get the requisition effectiveness.

Unit Effectiveness - Each unit requested is considered a demand, and each issue on time an issue. At the end of the period the number of issues is divided by the demands to get the unit effectiveness.

Times of Payment - Costs are not recorded until the material is received from procurement, received from repair, or received at destination after a shipment.

Minimum Procurements - Generally, as the unit price of an item goes up, the economical order quantity gets lower. Top management has decided that since the work-load in the Purchase Section is high, the minimum-purchase quantity will be for at least three months' purchase requirements.

Minimum Repair Quantity - For the same reasons stated for new procurements, the minimum quantity to be sent to repair is two months' expected repair requirements, if the material is available.

Process Generators

It has been previously mentioned that the inventory problem is surrounded by uncertainties in demand, times needed for various events and the regeneration of material. These uncertainties must be included in the simulation to represent reality. A useful tool for simulating stochastic processes such as these is the Monte Carlo technique.[5] The Monte Carlo technique needs a random variable, its probability distribution function, and a sequence of random numbers. The random numbers are provided by a random-number generator, which is a library function (RCM (I)). When the value of I is initialized at a 10-digit odd integer, the generator will provide uniformly distributed random numbers between 0 and 1. The following will be a description of the process generators, utilizing random numbers, to simulate the uncertainties within the program.

Demand Generator[6] - "High-demand items are satisfactorily described by the normal distribution, medium-demand items by the negative binomial distribution, and very low-demand items by the Poisson distribution."[7] One of the criteria for selection of a repairable item dictated that a regeneration rate of at least twenty units per year be used. This is considered a high-demand rate; therefore, a normal distribution is used to describe the demand input. Demand from end-use customers can enter

the system at Main Supply, Subsupply East or Subsupply West; therefore, three separate generators are used to allow varying demand input at each point. The random-time-interval generator is designed to provide the time between demand arrivals; therefore, the desired demands per month must be reduced to a mean time between demands. For example, if it were desired to create a demand of ten units per 30-day month with 1 standard deviation equal to 3.3 demands, then we would have a mean time between demand of 3 days and a standard deviation of 1 day.

Time Generators - Shipment paths exist between the primary physical locations, and are subject to variations in the time required to effect shipments. Transportation times approximate the normal distribution. Therefore, the same type of generator is used as in the demand generator. The characteristics of each path, such as type of transportation utilized, mean shipping time, standard deviation for shipment time, and cost to move one unit of a certain weight and cube on each path are inputs for the simulation.

Regeneration of Material - Return of material for possible repair after issue and the survival of material in repair are also subject to uncertainties. A Monte Carlo process is used to simulate these uncertainties. The percentages of possible return for repair and of material surviving repair are read in as inputs. When the program reaches a point where a decision is necessary, a random number is drawn for each unit and compared to the probability distribution read in. For example, if 90 percent will be returned for possible repair and the random number is 80, then the item will be returned; but had the random number been 95, the item would have been discarded.

Procurement and Repair Lead Time - Scheduling of work by the producers of new items and activities holding repair contracts cause uncertainties in the time necessary to complete these operations. The normal distribution function is used to generate procurement and repair lead times in this program, but the distribution could be replaced easily should it be determined that such times followed another type of distribution. As mentioned previously, a mean time and a standard deviation are necessary to activate the generator. These values could be easily obtained through a sampling project.

Time Control Mechanism

It was necessary to relate the operations within the system to time, because the behavior of the system is time-dependent. The precise arrival time of material could affect the effectiveness figures that are the most commonly used measures of performance. The dynamic aspect of the system is created through use of a time-dependent queueing network. The inventory problem is often described as a queue (waiting line) problem because of the backorders that accumulate when the system is temporarily out of material. Constructed within this simulation are many different methods of judging performance. These were all incorporated because different methods are needed to compare the results of various types of experiments.

The physical system shown in Figure 2 was analyzed, and it was determined that there were sixteen times when the program had to momentarily pause and update the state variables or generate new times for

SIGNIFICANT TIMES

SWITCHING* CODE	TIME LOCATIONS	ARRAY SIZE	DEFINITION
TMSW (1)	TNNMW ( )	10	Time of next new shipment from main to SSW
TMSW (2)	TNNME ( )	10	Time of next new shipment from main to SSE
TMSW (3)	TNNCM ( )	10	Time of next new shipment from Procurement to main
TMSW (4)	TNNFM ( )	10	Time of next new shipment from repair facility to main
TMSW (5)	TNRFF ( )	10	Time of next repair lot scheduled to complete repair
TMSW (6)	TNRMF ( )	10	Time of next repair shipment from main to repair
TMSW (7)	TNREM ( )	10	Time of next repair return from east to main
TMSW (8)	TNRWM ( )	10	Time of next repair return from west to main
TMSW (9)	TNDLN	1	Time of next demand at main from local customers
TMSW (10)	TNOWN	1	Time of next replinishment order from west at main
TMSW (11)	TNOEM	1	Time of next replinishment order from east at main
TMSW (12)	TNDEE	1	Time of next demand at east from east customers
TMSW (13)	DNDWW	1	Time of next demand at west from west customers
TMSW (14)	TNRR	1	Time of next requirement review
TMSW (15)	TNPR	1	Time of next period review
TMSW (16)	TNDUP	1	Time of next demand updating

*This will always contain the lowest value of time for its corresponding time arrays.

TABLE I

subsequent events. Table I provides a list of these significant times and a brief description of their meaning.

When the system simulation is activated, initial times are generated for TMSW (9), TMSW (12), and TMSW (13), and times are put in for TMSW (14), TMSW (15), and TMSW (16). All other TMSW's have very large values, and the symbol TIME is initialized at 0.0. The program searches the array TMSW and finds the lowest value for action. As an example, when the switching routine determines that TMSW (12) has the lowest value in the TMSW array, we see that a demand is expected from a customer at Subsupply East. When entering the TMSW (12) routine, the first action necessary is to update TIME to the value of TMSW (12) used to switch to this routine. As the demands are for one item it is now considered that a demand has been received, and either an issue is made or a backorder established. If an issue has been made, the Monte Carlo draw technique is used to determine if the returned part is capable of repair and is to be returned for possible repair. If the item is to be returned, then the time generator is used to generate a time in shipment. This shipment time is added to the updated value of TIME, and a time of arrival is thus determined for the material at Main Supply. As a change has affected the asset picture, the On Hand plus due, plus backorders must be compared with two times the average demand. If a deficiency exists, then an order is placed to arrive at Main Supply at TIME + 2 days for the deficiency plus an average month's demand. The last step is to generate the time until the next demand by using the demand generator and adding this value to TIME. The resulting value

is stored in TMSW (12) and will await its proper time in the switching routine.

Of the sixteen values used in the switching routine, the first thirteen, TMSW (1) through TMSW (13), directly relate to the receiving of demands, issue of material, shipment of material, and updating of state variables. There are three additional times used, and a brief description of each follows.

TMSW (14) Time of Next Requirements Review. (TNRR)

Periodically it is necessary to compare system assets vs. system requirements and make a decision to buy, repair or await the next review. The rules that allow the program to make this decision are the "Repairable Decision Rules," and are considered to be the inventory operating policy. The frequency of review is important, and the closer the reviews, the better will be the decisions. However, physical limitations sometimes prevent daily or even monthly reviews. A set schedule is necessary so that safety-level adjustments can be made to cover this uncertain period. The time between reviews is an input value to allow matching of the simulation to reality or evaluating the results if an existing policy is modified.

TMSW (15) Time of Next Period Review. (TNPR)

To perform an analysis of the simulation, it is necessary to generate statistics and collect data for review. Top management is normally familiar with certain key statistics on a regular schedule, and it is necessary to use these same statistics and schedules when running the simulation for ease of explanation of the results when completed. The

simulation to be presented utilizes a 30-day month as the reporting period.

TMSW (16) Time of Next Demand Updating. (TNDUP)

The problem of adjusting the forecasts of future demand from experienced demand is of vital importance to the inventory manager. This simulation will use single exponential smoothing with the value for the smoothing weight being an input. Many approaches could be used, as this is a very controversial area and the testing necessary to determine the optimum method for a particular situation is a complete study in itself. The demand updating was established as a separate routine so that, if desired, tests could be planned to optimize this function.

CHAPTER III

DESCRIPTION OF REPAIRABLE DECISION RULES

General

The mathematical model for the repairable decision rules was used at the United States Navy Ships Parts Control Center, Mechanicsburg, Pennsylvania, prior to its adoption of new rules for the Unified Inventory Control Point in late 1966. Certain refinements that were included in the original are not presented here, but the basics are the same. The rules are possibly not the optimum for the physical system presented, but are well developed and could be adjusted to fit almost any repairable-item management problem. The financial climate in which the rules are to be used has a great deal to do with the values assigned to the variables that control it.

Definition of Terms

The terms used in the presentation of the repairable decision rules will be defined here, with a description of data source and possible limitations. The definitions will also include the applicable FORTRAN symbols, because the formulas will be constructed using these symbols.

On-Hand Ready-for-Issue (OHM) - The on-hand ready-for-issue value is a state variable, and the most recently updated value is used during the requirements review.

Due from Repair (DUFR) - The most recently updated value for the quantity of items due from repair. The actual assets being returned

to Main Supply from repair could be several units less than this value, because the possibility exists of some items being surveyed while at the Repair Facility. DUFR is incremented when items are shipped to repair and decremented when material is actually received at Main Supply.

Due From Contract (DUFC) - The most recently updated value for the quantity of items due from procurement. DUFC is incremented when a requirements review is held and an order is placed. DUFC is decremented when the new material ordered is actually received at Main Supply.

Hard Assets (HARDA) - HARDA = OHM + DUFR + DUFC. Hard assets are the sum of assets on hand at Main Supply, firm dues from contract, and repair.

On-Hand, Not Ready for Issue (OHMR) - The most recently updated value representing the items held at Main Supply awaiting possible induction into the repair cycle. This item is incremented upon each receipt from Subsupplies or local customers at Main Supply, and decremented when the requirements review indicates induction into the Repair Facility is necessary.

Procurement Lead Time (PLT) - The time period measured from the time of the requirements review until the material is received at Main Supply and placed in the on-hand ready-for-issue account. The mean procurement time (TMU11) is an input value used in the procurement lead time generator, and also used as the value for PLT. The value is expressed in months.

Repair Lead Time (RLT) - The time period between the requirements review and the receipt of the material at Main Supply, when it is placed

in the on-hand ready-for-issue account. The value is computed by taking the sum of the mean repair time (TMU10), mean transportation time from Main Supply to Repair Facility (TMU4), and mean transportation time from Repair Facility (TMU5). The value is expressed in months.

Predicted Carcass Return Rate (BP) - The rate at which issues are expected to result in carcasses being returned for possible repair.

Predicted Carcass Survival Rate (AP) - The rate at which items in Repair Facility are expected to survive and become material on hand ready for issue.

Procurement Safety Level (PSL) and Repair Safety Levels (RSL) - The safety levels are added in the reorder points to cover uncertainties and provide a means of adjusting levels of stock to attain a desired level of effectiveness. Many systems are employed to provide safety levels, but the system in this simulation provides a constant safety level based on the need to protect at least the unprotected period between the actual occurrence of a requirement and the next scheduled requirements review. As the simulation is a testing device, an input value (AJP) is used to adjust this value as necessary.

Backorder File Main (TOBOFM) - Backorders, or obligations as they are often called, are requirements that are unfilled and must be considered in addition to the forecasted demand in the future. The file is incremented whenever a requirement is received and material is not available, and decremented when backorders are released.

Demand Forecast (DEMFOR) - The best available forecast of demand for the next period, based on past experience.

Holding Cost Rate (HOCTR) - Rate, expressed as a percentage of unit cost, represents the cost to hold one unit of inventory for one year. It is composed of storage costs, interest rates and obsolescence rate.

Unit Price (UNPRN) - Cost of one unit of material new.

Order Cost (ORDCT) - The administrative costs necessary to process one order.

Procurement Economic Order Quantity (NEOQ) - When a decision has been reached that a buy is to be made, the next question is "How much?" The classic EOQ formula is used, except instead of using two years of expected demand (24 x DEMFOR), two years of expected attrition 24 x DEMFOR x (1 - AP x BP) is used.

The formula is as follows:

$$\text{NEOQ} = \sqrt{\frac{24 \times \text{DEMFOR} \times (1 - \text{AP} \times \text{BP})}{\text{HOCTR} \times \text{UNPRN}}}$$

The reader is reminded that a minimum three-month procurement is necessary: therefore, the minimum EOQ is equal to 3 x DEMFOR x (1 - AP x BP).

Repair Economic Order Quantity (NREOQ) - The formula for the procurement EOQ is followed with two exceptions. First, the two-year demand forecast should be modified to a two-year projection of what will enter repair (24 x DEMFOR x AP x BP). Second, the unit price should be changed to the cost per unit for an item to be repaired. This is accomplished

by multiplying UNPRN x RCP (RCP being the cost of repair expressed as a percent of the new procurement unit price). The formula is as follows:

$$\mathrm{REOQ} = \sqrt{\frac{24 \times \mathrm{DEMFOR} \times \mathrm{AP} \times \mathrm{BP}}{\mathrm{RCP} \times \mathrm{UNPRN} \times \mathrm{HOCTR}}}$$

The reader is reminded that a minimum two-month repair induction is necessary if the material is available. Therefore, the minimum REOQ is equal to 2 x DEMFOR x AP x BP.

Procurement Reorder Point (PRP) -- This is the longest period to be protected in the requirements review. If it takes 12 months to receive a shipment from date of order, and 20 demands are expected each month, we must have at least 12 times 20 either on hand, on order, or a combination of both. In addition, all backorders must be included in addition to the demand forecast. The final item is the procurement safety level, which allows covering the uncertainties to obtain a desired level of effectiveness. The formula is as follows:

$$\mathrm{PRP} = (\mathrm{PLT} \times \mathrm{DEMFOR}) + \mathrm{TOBOFM} + \mathrm{PSL}$$

Repair Reorder Point (RRP) - This is the shorter of the two periods that must be protected in the requirements review. The formula is the same as for the procurement reorder point, except that the repair lead time and repair safety level are used. The formula is as follows:

$$\mathrm{RRP} = (\mathrm{RLT} \times \mathrm{DEMFOR}) + \mathrm{TOBOFM} + \mathrm{RSL}$$

Expected Assets During Protection Period (EXASSP) - This is the total of all assets that can be received and converted into material on hand

at Main Supply within a PLT. It is composed of:

1. OHM + DUFC + DUFR --- Hard assets.
2. AP x OHMR --- Regeneration from those on hand at Main Supply awaiting repair.
3. AP x BP x DEMFOR x (PLT - RLT) --- Regeneration over the first several months that will be returned to Main Supply and added to the OHMR. These will be inducted and will return from the Repair Facility prior to the end of the PLT.

Theory of the Repairable Decision Rules

How much to buy and how much to repair have been answered by the EOQ formulas presented in the definitions. It is now necessary to explain when to buy and when to repair. When the expected assets during the protection period (EXASSP) -- same time period as a procurement lead time -- are greater than the procurement reorder point, a buy is not necessary; however, the hard assets (HARDA) must be compared with the repair reorder point (RRP) to see if it is necessary to repair. The hard assets (HARDA) must be reduced prior to this comparison by the amount of dues from contract that will arrive after a repair lead time, as these assets might not be received soon enough to satisfy any demands in the period PLT - RLT. If HARDA is less than RRP, then the lesser quantity of on-hand available to be repaired (OHMR) or the repair EOQ plus deficiency to RRP must be inducted into repair. Had the EXASSP not been greater than PRP, then the deficiency plus a procurement EOQ would have been bought and the full quantity OHMR would have been inducted into the Repair Facility. Figure 3 presents a schematic of the above.

SCHEMATIC OF REPAIRABLE DECISION RULES

$$\text{PRP} = (\text{PLT} \times \text{DEMFOR}) + \text{PSL} + \text{TOBOFM}$$

$$\text{RRP} = (\text{RLT} \times \text{DEMFOR}) + \text{RSL} + \text{TOBOFM}$$

$$\text{HARDA} = \text{OHM} + \text{DUFR} + \text{DUFC} - (\text{DUFC in period between RLT and PLT})$$

$$\text{EXASSP} = \text{OHM} + \text{DUFR} + \text{DUFC} + (\text{AP} \times \text{OHMR}) + (\text{AP} \times \text{BP}) \times \text{DEMFOR} \times (\text{PLT} - \text{RLT})$$

$$\text{NEOQ} = \sqrt{\frac{24 \times \text{DEMFOR} \times (1 - \text{AP} \times \text{BP})}{\text{HOCTR} \times \text{UNPRN}}}$$

$$\text{NREOQ} = \sqrt{\frac{24 \times \text{DEMFOR} \times \text{AP} \times \text{BP}}{\text{RCP} \times \text{UNPRN} \times \text{HOCTR}}}$$

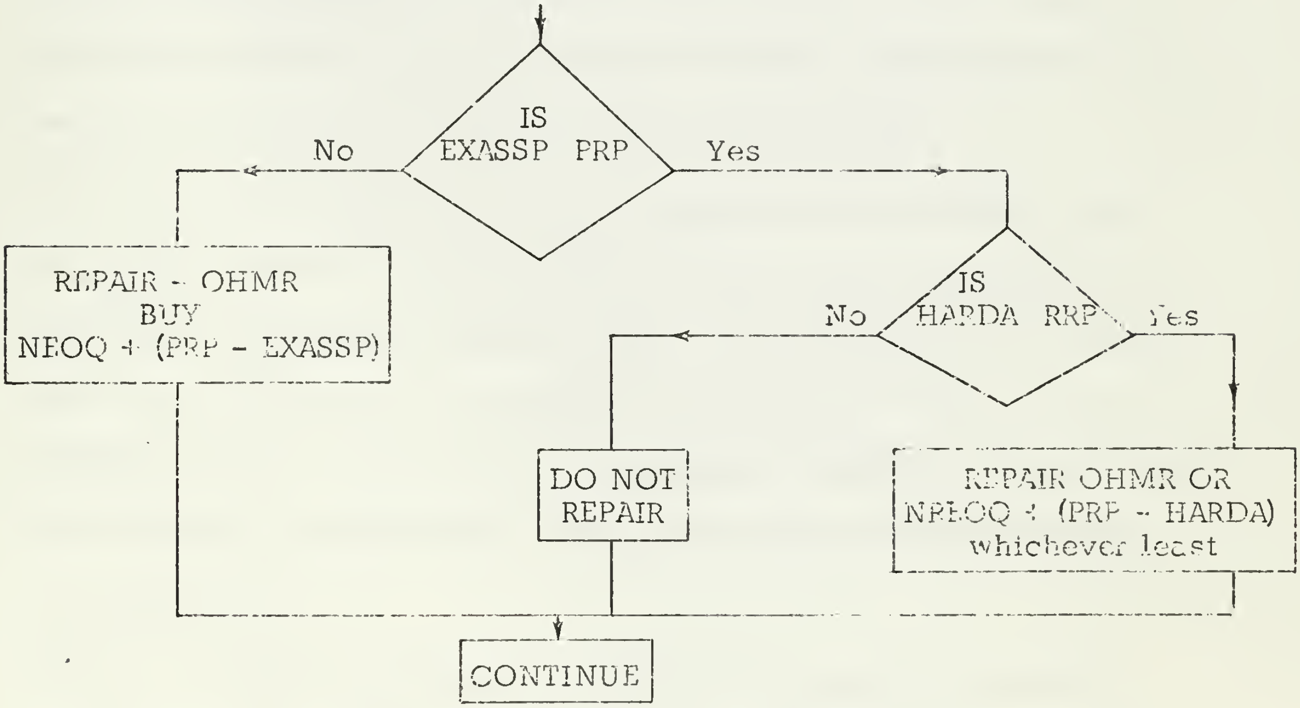

Figure 3

CHAPTER IV
INTEGRATED SIMULATION MODEL

When the mathematical model for repairable-item management is combined with the queueing network that describes the actual system, the package is complete and a simulation tool is now available. In designing and building the integrated simulation model, emphasis was placed on making the model as general and as flexible as possible to allow a variety of tests to be performed. The use of subroutines was considered; however, it was finally decided to keep all routines used in the computer program within the main program, but to identify their position by an assigned group of statement numbers. Table II shows the routines and their assigned statement numbers. The following comments are pertinent to the input and output of the model.

Input - Since the model has been made general and as flexible as possible, it was necessary to include many values as inputs, to prevent the necessity of changing the program itself. To keep track of these values, and to know what was used to obtain a specific set of output, a display of the output was created for ease of analysis. Appendix C is an example of this display, together with a listing of the data that were read into the computer.

Output - To attain the objective of creating an integrated simulation model that was capable of testing many different alternatives, it was necessary to obtain many output values for possible use in the eventual analysis. Appendix D is a sample of the output that was obtained by

TABLE II

LOCATIONS OF ROUTINES

FORTRAN PROGRAM STATEMENT NUMBERS From	To	ROUTINES
0	150	Reads, Formats, Writes, Misc.
151	200	Switching Routine
201	250	Receipt of new material shipment at Subsupply West from Main
251	300	Receipt of new material shipment at Subsupply East from Main
301	400	Receipt of new shipment at Main Supply from procurement or repair
401	450	Exit of material from Repair Facility
451	500	Receipt of shipment at Repair Facility from Main Supply
501	550	Receipt at Main Supply of item capable of repair from Subsupply East
551	600	Receipt at Main Supply of item capable of repair from Subsupply West
601	650	Receipt of demand at Main from local customers
651	700	Receipt of demand at Main from Subsupply West
701	750	Receipt of demand at Main from Subsupply East
751	800	Receipt at Subsupply East of demand from local customers
801	850	Receipt at Subsupply West of demand from local customers
851	900	Requirement review
901	950	Period review
951	999	Main Supply demand update
1001	1049	Plot routines
1050	1050	Return for additional simulation

reading into the computer the data listed in Appendix C. The emphasis for display in Appendix D was placed on the interactions of state variables; therefore, the report period was established at a ten-day interval. The sampling of the values every ten days provides a smoother picture of the way the values are in fact changing through time. When most tests are run the reporting period is thirty days — the normal unit of time in which performance is judged. Changing the reporting period will have no effect on the eventual expectation of the model, as it is just a pause to examine performance or to present values of state variables.

The common uses of the integrated simulation model will not be for studying the interaction of the many state variables, but rather the evaluation of different alternatives available to the inventory manager. As the model is probabilistic, it can not be used effectively as a short-run predictive device. The model does become effective, however, when the measures of effectiveness and average costs approach closely the expectation for a given set of input values. It is necessary to examine the values that will be used in the eventual analysis to insure that they approach the expectation within very high confidence limits. The values must be checked for variances of the means as the number of trials increases. Running comparisons must also be made of the means obtained on additional runs using different random-number-sequence listings. The "F test for equality of variances" has been utilized.

Uses For The Integrated Simulation Model

In general, simulation has been used for the following purposes:

1. As a problem-solving technique, i.e. to obtain the answer to a specific numerical problem.
2. As an experimental method, i.e. to explore the nature of a system being simulated.
3. As an indirect method of analysis, when the systems under consideration cannot be analyzed using direct or formal analytical methods.[8]

Categories of tests or modes of analysis that can be performed on the present model are:

1. Optimization Analysis - Testing to find the proper operating values for system parameters to maximize performance while minimizing costs.
2. Sensitivity Analysis - When an operating policy has been selected, one can determine the effect on the costs and effectiveness if deviations are made from the optimum policy.
3. Systems Design - It is possible that the present network of supply points is not the optimum and that consideration should be given to modification. Such modifications can be tested on the model.
4. Operating Policy Analysis - As an example, the present system should have a firm policy on the mode of transportation to be used when shipping new parts or returning parts to be repaired. This policy should be reviewed to determine if it is still optimum when the cost of transportation is changed. In addition, the limitation placed by the inventory manager

on how much should be spent on repair needs to be examined periodically. The model gives one this ability to analyze effects of policy changes.

5. Demand Forecasting - Technique for demand forecasting are varied, and testing with the simulation will help optimize the choice of forecasting method without disrupting the actual operation.

Specific questions or situations posed by outside sources could be answered by the model. For instance, management is considering a cut in the funds available to the inventory department, but they would like to know how this will affect the effectiveness of meeting customer demands. Also consider the case where the inventory department is not asked, but is told that only a limited amount of funds are available. The model can now be used to test alternatives available to reduce spending but maximize effectiveness at the new level of funding.

Limitations

Monte Carlo simulation solutions have some disadvantages which are not present in analytic solution methods. There is still the problem of statistical variations and experimental design inconsistencies that are present in direct experimentation of the real situation. It is mandatory that a large enough sample be taken and this sample compared to others taken with a different series of random numbers. Also the simulations must be run long enough to reach steady-state conditions. It therefore follows from the above that if a problem can be described by a realistic,

analytic model that can be mathematically manipulated to obtain an optimum solution, it possesses an important advantage over the Monte Carlo simulations.

It is of vital importance to understand the variables used in the program and to collect data from the real world to correspond with the intended use. Poorly-collected data will have a big effect on the outcome of some experiments. The term "some" is used because as long as the same data are used, alternative tests could still be effective, even though the data are poor.

CHAPTER V

A SAMPLE PROBLEM EVALUATION

Problem Statement

Selecting a problem to examine when the system is a hypothetical one presents some problems. In an effort to circumvent these problems, it will be assumed that values displayed in Appendix C represent the optimized values being used in the operating policy of a hypothetical firm. In addition, realistic transportation times and costs were obtained for representative weights and cubes from the Military Traffic Management and Terminal Service (MTMTS), Washington, D. C., based on the terminals at Pearl Harbor, London, Norfolk, and Long Beach. Table III presents the data received from MTMTS and used in the following problem.

In the operating manual used by the employees responsible for selecting items to manage as repairables, the following might appear:

> Repairable Item. An item which, through rework, test and check, modification, or replacement of parts, can be returned from an unusable condition to performance approximating that of a new item at reasonable cost (80 percent or less of the new unit price).

The range of items managed by this firm vary from very small high-priced items to very large high-priced items. The definition of a repairable item appears sound, but one may ask whether the constraint of 80 percent or less of the new unit price is proper for all items managed as repairables by the firm.

TRANSPORTATION TIMES AND COSTS

LOCATION	COST						TIME	
WEIGHT (LBS)	20	50	100	150	200	300	MEAN	1 STD
CUBE (FT)	1	2	3	4	6	10		
LONDON (SUBSUPPLY EAST)								
a) Surface	6.00	6.00	6.00	9.00	12.00	18.00	25	5
b) Air	14.00	14.00	15.00	22.50	30.00	45.00	2	1
PEARL HARBOR (SUBSUPPLY WEST)								
a) Surface	7.00	7.00	7.60	11.40	15.20	22.80	32	7
b) Air	24.00	24.00	33.00	49.50	66.00	99.00	3	1
LONG BEACH (REPAIR FACILITY)								
a) Surface	6.00	6.00	6.25	9.37	12.50	18.75	26	3
b) Air	18.00	18.00	25.00	37.00	50.00	75.00	1	.5

TABLE III

Method of Approach

The basic alternatives in the management of an inventory of items are either management of them as consumables or management of them as repairables. Therefore it is possible to compare the average monthly costs under consumable management vs. the average monthly costs under repairable management. It must be noted that average monthly costs under repairable management will be dependent upon the limits placed upon repair costs to be incurred by the repairing activity (RCP).

It is necessary that the firm have an effectiveness goal. This level of effectiveness may be attained by either method of management, but the cost of operating under the two alternate methods of management (repairable vs. consumable) may not be the same. The purpose of this study is to show under what circumstances repairable management would be more favorable than consumable-item management.

The method of simulation for a repairable has been described, and as the construction of the procurement reorder point is the same for repairable or consumable management, only a minor change is necessary. To manage an item as a consumable, regeneration of material will be zero: therefore it is necessary to set the Monte Carlo draw so that all material after issue will be used and not returned for possible repair.

As mentioned, it will be necessary to simulate an item once as a consumable; then again as a repairable. The method used to adjust stock levels, so that the effectiveness under both methods of management will be equal to each other and also to the goal, is to adjust the safety level, using an input multiplier (AJP).

When the input values have been decided upon, it is then necessary to run several trial simulations of varying lengths to determine the number of periods that must be simulated, so that the values that are to be used in the cost comparison are within acceptable limits of confidence. After the length of the simulation runs are known, it is then necessary to run the simulation several times, using different random-number series, until mean values of the desired output are within the acceptable confidence limits.

The costs applicable to managing an item as a consumable are as follows:

1. Average monthly procurement costs.
2. Average monthly cost to ship new items to the Subsupply points.

In addition, for a repairable there are the following costs:

1. Average monthly actual repair costs. (Will vary as the value of RCP changes).
2. Average monthly costs to move repairable items, both to Main Supply to await repair, and to and from the Repair Facility.

Not included in the above cost comparisons is a one-time investment-level adjustment, but its importance should be recognized. The investment-level formulas are as follows:

(a) Consumable item

$$((PLT \times DEMFOR) + PSL + .5 \times EOQ) \times UNPRN$$

(b) Repairable item

$$(PLT \times (1. - AP \times BP) \times DEMFOR + PSL + .5 \times EOQ) \times UNPRN$$

Plus

$$(RLT \times AP \times BP \times DEMFOR + RSL + .5 \times REOQ) \times UNPRN$$

This is a common method of presentation, but is not the only method available. Methods of accounting vary: however, consistency once a procedure is adopted appears to be the rule. As this is a one-time adjustment, it is hard to pro-rate these costs unless the life of the item is known. Caution should be exercised if the item being reviewed is considered to have a short life, because this one-time adjustment could affect the final judgment.

RESULTS

The basic objectives of this thesis were:

1. To build a repairable-item inventory-management model using a digital computer.
2. To show that this model could be used to investigate the appropriateness of certain operating policies used in repairable-item inventory management.

The model has been run successfully and is believed to give realistic response to changes that would normally be expected in an inventory of repairable items.

A series of tests was run using a goal of 77 percent effectiveness. Effectiveness is defined as the ratio of requisitions filled to requisitions presented to the main supply point. Preliminary tests were run to select the number of months that would need to be simulated to compute system effectiveness values at a 95-percent confidence level. For the simulation of a repairable item, it was determined that 1000 months would be sufficient: however, for a consumable item, 2500 months are necessary. The additional time required for the simulation of a consumable is believed to be caused by the long recovery period after a problem develops that would cause material shortages. For a repairable item, material will be entering the system at more frequent intervals (from repair and from procurement) which will dampen the fluctuations in effectiveness measures. It is felt that this increased "stability" of the system is a basic phenomenon of a repairable-item inventory system. This would tend to be

one of the fringe benefits of repairable-item management over consumable-item management.

When adjusting the safety levels in order that all simulation runs (for a specific weight, cube, and unit price) attain the 77 percent, it was found that the requisition-effectiveness values were very sensitive to minor changes in the safety levels. Therefore, if a simulation run could be obtained with an effectiveness figure of plus or minus .5 to the desired 77 percent, it was considered acceptable. The results of the simulations are displayed in Table IV. This matter of the sensitivity of effectiveness to inventory levels would probably be expected in any inventory model. Time did not permit a true sensitivity analysis of effectiveness versus the various inventory safety levels. Anyone using this model extensively would want to undertake such a sensitivity analysis.

It was expected that changes to the actual repair cost, expressed as a percentage of original cost (RCP), would produce different requisition effectiveness values: however, the changes were so small that they can be ignored. RCP is used within the program only when computing the economical repair quantity. The operating-policy constraint of repairing at least two months' requirement negates any significant effect caused by changes to RCP. Because of this, the analysis of costs of managing items as consumable or repairable becomes less complex.

This circumstance of the EOQ being less than the minimum order quantity is again undoubtably an inherent characteristic of repairable-item inventory systems, because repairable items are generally more

SIMULATION DATA

ITEM VALUE	200.00			500.00			1000.00		
Weight (lbs)	50	200	300	50	200	300	50	200	300
Cube (ft^3)	2	6	10	2	6	10	2	6	10
CONSUMABLE (AVGS)									
New Procurement	5,890	5,909	5,909	14,718	14,762	14,723	29,429	29,391	29,439
New Trans. Cost	106	224	335	106	224	333	106	223	336
Total (Avgs)	5,996	6,123	6,234	14,824	14,986	15,056	29,535	29,614	29,775
CONSUMABLE INVEST. LEVEL	78,846	79,368	79,619	197,115	198,421	199,047	394,230	396,984	398,246
REPAIR (AVGS)									
New Procurement	1,110	1,119	1,130	2,796	2,768	2,817	5,587	5,532	5,629
New Trans. Cost	105	222	333	106	223	333	106	223	333
Repair Trans. Cost	640	1,479	2,217	638	1,476	2,217	638	1,476	2,217
Sub total (Fixed Costs)	1,855	2,820	3,680	3,540	4,467	5,367	6,331	7,231	8,179
Repair (RCP = 1.0)	4,784	4,780	4,768	11,923	11,951	11,908	23,846	23,901	23,816
Total Cost of Repair (RCP = 1.0)	6,639	7,600	8,449	15,463	16,418	17,275	30,177	31,132	31,995
REPAIR INVEST. LEVEL	60,550	60,245	60,551	151,527	150,613	151,378	303,319	301,440	302,757
LEVELS ADJUSTMENT	13,196	19,123	19,068	45,488	47,808	47,669	90,911	95,544	95,489
RCP VALUE*	.865	.691	.555	.946	.880	.814	.973	.936	.907

*Value of RCP when consumable management costs equal repairable management costs.

TABLE IV

costly and therefore yield low EOQ values. Any extensive investigation of this model would include a study of the cost-effect of the external constraints, such as the 2-month minimum economical repair quantity and the 3-month minimum economical procurement quantity.

It was necessary to find the value of RCP that would cause the costs of consumable management to equal total costs of repairable-item management. It is recalled that repairable-item management costs are composed of the following:

1. average monthly procurement costs
2. average monthly costs to ship new items to Subsupply points
3. average monthly costs to move repairable items, both to Main Supply to await repair, and to and from the repair facility
4. average monthly actual repair costs (will vary as the value of RCP changes)

Items 1, 2, and 3 can be summed, and item 4 is varied until a value of RCP is obtained that will achieve equality with consumable-item-management total costs. The results are shown on the last line of Table IV.

It can be seen that the physically smaller items that would result in reduced transportation costs are the better candidates for repairable-item management. More important is the knowledge that a fixed criterion, e.g. 80 percent or less of new-unit price, is unrealistic as a single operating policy. The RCP (actual cost of repair expressed as a percentage of new cost) that is the dividing point between economical repair management and consumable-item management must be developed for

each firm as a function of the weight, cube, unit cost, and transportation costs for each item. The type of analysis presented here would be helpful in developing such relationships.

The present computer program could be used to explore the benefits to be derived from changing the operating rules and procedures relative to demand forecasting, safety-level determinations, and forecasting of regeneration rates. By such manipulation of the operating rules, one could obtain an optimal set of repairable-item inventory management decision rules.

The costs associated with building, maintaining and using a simulation model that is complete enough to accurately describe the physical characteristics and operating policies of a firm are large. The dividends that would accrue through better management and understanding of the system will more than compensate for these costs. The simulation model utilized a General Electric 625 computer. It required approximately 20,000 core storage locations, and required 3 minutes of processor time for each run.

Examination or solving of problems by the simulation technique provides a great deal of understanding of the interdependence of the many variables that might not otherwise be possible. Further, the ability to propose modification and be able to study, in the present, the future effect is invaluable. The simulation results are not the ultimate answers, and must be evaluated with other knowledge that is acquired through experience and common sense. Thus, simulation is another useful tool which can be used to build sound inventory-management decisions.

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APPENDIX A

GLOSSARY OF FORTRAN TERMS

GLOSSARY OF FORTRAN TERMS

AA	Actual carcass survival rate.
A	A counter that sums the number of backorders that are used in computing the average time that a backorder is outstanding.
(A1, A2, A3, A4)	Nomenclature of item to be simulated, not to exceed 20 letters.
(A5, A6, A7, A8)	Location of Main Supply for simulation.
(A9, A10, A11, A12)	Location of Subsupply West for simulation.
(A13, A14, A15, A16)	Location of Subsupply East for simulation.
(A17, A18, A19, A20)	Location of Repair Facility for simulation.
(A21, A22, A37, A38)	Procurement safety level. The formula to be used in the safety level computation is displayed on the input sheet for future reference.
(A23, A24, A39, A40)	Repair safety level. The formula to be used in the safety level computation is displayed on the input sheet for future reference.
AJP	This is an input value that is used internally to adjust the safety procurement level.
AJR	This is an input value that is used internally to adjust the repair safety level.
ALOG ( )	A function that takes the logarithm of a number. It is used in the normal distribution time generator.
AMODE AMODW	Moving average of demand at Subsupply East and Subsupply West respectively.

ANUC	Average cost per period of all material received from contract.
AP	Predicted carcass survival rate.
ARC	Period average cost of all material repaired by the Repair Facility.
ATC	Period average of total costs.
ATNC	Period average costs for movement of new material.
ATRC	Period average repair associated transportation costs.
AWS	Period average investment level (expressed in dollars).
BB	Actual carcass return rate.
BOFE BOFW	These are the backorder file designators for Subsupply East and Subsupply West respectively. They indicate only the number of backorders that are outstanding at any given point in time. There is not an aging routine to determine how long a backorder was in fact outstanding.
CARC	Cumulative costs of all material repaired by the Repair Facility.
CAVBOG	Average time that a backorder remains outstanding.
CAWS	Cumulative investment level (expressed in units).
CCURDE	Cumulative demand at Subsupply East.
CCURDW	Cumulative demand at Subsupply West.
CEISS	Cumulative number of issues on time at Subsupply East.
COS ( )	A function that determines the cosine of an angle. It is used in the normal distribution time generators.

CPNUC	Cumulative costs of all material received from contract.
CPRDM	Cumulative number of requisitions for material received at Main Supply.
CPTNC	Cumulative costs for movement of new items.
CPTRC	Cumulative costs of all repair associated transportation.
CPUDM	Cumulative number of units demanded at Main.
CREFFE	Cumulative requisition effectiveness at Subsupply East.
CREFFM	Cumulative requisition effectiveness at Main Supply.
CREFFW	Cumulative requisition effectiveness at Subsupply West.
CRISSM	Cumulative number of requisitions issued on time at Main Supply.
CTIEMP	Cumulative time of all individual outstanding backorders.
CUBE	Cube of the item to be simulated expressed in cubic feet.
CUEFFM	Cumulative unit effectiveness at Main Supply.
CUIOTM	Cumulative number of units issued on time at Main.
CURDE	Demand per period at Subsupply East.
CURDEM	Records the amount of demand recorded at Main Supply during a period. It is used in the demand update routine.
CURDME	Monthly demand counter used to forecast demand at Subsupply East.

CURDMW	Monthly demand counter used to forecast demand at Subsupply West.
CURDW	Demand per period at Subsupply West.
CWISS	Cumulative number of issues on time at Subsupply West.
DEMFOR	Demand forecast at Main Supply used in the requirements review.
DUEE	Material due at Subsupply East from Main Supply.
DUEW	Material due at Subsupply West from Main Supply.
DUFC	The number of units due at Main Supply from contract.
DUFR	The number of units due from repair at Main Supply.
EISS	Number of issues on time at Subsupply East per period.
EOQ	Procurement economic order quantity. It is the larger of NEOQ or MINEOQ.
EXASSP	Expected assets to be available during a production lead time. Is the sum of On Hand, due from repair, due from contract and expected regeneration.
EYE	A symbol used by the plotting routine to plot the extreme right and left boundaries of the graph.
FLOAT ( )	A function that converts real numbers into integer numbers.
HARDA	Hard assets. These assets consist of items that are due from repair, due from contract plus those that are on hand at Main ready for issue.
HOCTPR	Cost to Hold. Input value expressed as a percent.
HOCTR	Cost to Hold. The value is used in the requirements review in the economic

	order quantity determination. Obtained by dividing HOCTPR by 100.
I	The initializing value for the random number generator. It must be a ten digit odd number.
KOUNED	An input value that controls the number of simulations that are to be accomplished on a given computer run.
KOUNST	External input that will number the output computer runs.
KT	A counter that is used to delay the recording of any statistics until the simulation has run for 25 periods. This delay is necessary as initial values are only provided for the on hand values and time is necessary for all paths of the simulation to have representative values.
L ( )	An array that controls the number of columns that can be plotted in a graph.
MINEOQ	The minimum procurement economic order quantity.
MINREQ	The minimum economic repair induction quantity.
MOD (X,Y)	A remaindering function for integer numbers that gives the remainder when X is divided by Y.
NEOQ	The economic order quantity computation for procurements.
NOHE NOHW NOHM ABC NELT SELT SKOUNT MINEOQ NT AT ALINE	These symbols are used in the sequencial operation of the program to convert either from a fixed point to a floating point or visa-versa as necessary to prevent mixed mode operation.
NL	A device which enables the plotting symbols of the graph to be plotted, line by line, from the top of the graph to the bottom.

NLINE	The designation of the midpoint of the incremental ranges of the vertical scale.
NPER	It is a counter that counts the number of periods that are being simulated.
NREOQ	The economic repair induction quantity computation.
NZ NA NB	These symbols are index values used in determining the proper sequence of the plotting routines.
N1	Input value representing index of position in TEMPB array that designates scale values to be used on LEFT scale of Main Supply plot.
N2	Input value representing index of position in TEMPB array that designates scale values to be used on RIGHT scale of Main Supply plot.
N3	Input value representing index of position in TEMPB array that designates scale values to be used on LEFT scale of Subsupply West plot.
N4	Input value representing index of position in TEMPB array that designates scale values to be used on RIGHT scale of Subsupply West plot.
N5	Input value representing index of position in TEMPB array that designates scale values to be used on LEFT scale of Subsupply East plot,
N6	Input value representing index of position in TEMPB array that designates scale values to be used on RIGHT scale of Subsupply East plot.
N7	Input value representing index of position in TSCAB array that designates scale values to be used on LEFT scale of Reorder point plot.

N8	Input value representing index of position in TSCAB array that designates scale values to be used on RIGHT scale of Reorder point plot.
N9	Input value representing index of position in TSCAB array that designates scale values to be used on LEFT scale of Cost data plot.
N10	Input value representing index of position in TSCAB array that designates scale values to be used on RIGHT scale of Cost data plot.
OHE	On hand stocks at Subsupply East available for issue. The value is initialized with Subsupply East starting with an on hand balance equivalent to 2 months of expected demand.
OHM	Material On Hand at Main Supply available to meet demands from local Main Supply customers plus demands from Subsupply East and Subsupply West to replenish their stocks. The initial value is the expected demand per month at East, West and Main times the production leadtime.
OHMR	The number of units on hand Main that have been returned from Subsupply East, Subsupply West and local Main. It is intended that these should be held until a requirements review dictates induction into the Repair Facility.
OHW	On hand stocks at Subsupply West available for issue. The value is initialized with Subsupply West starting with an on hand balance equivalent to 2 months of expected demand.
ORDCT	Order cost. The value is used in the requirements review.

PAWS	Period investment level (expressed in units).
PBR	An input value that specifies the number of periods to be simulated on a particular computer run.
PLT	Production Lead Time. Measured from the time it is determined that an order is necessary until the time that the material will arrive at Main Supply available for issue. It is expressed in months and assumes the value of TMU11.
PNUC	Costs of all material received from contract during period.
PP	Predicted carcass return rate.
PRC	Cost of all material repaired by Repair Facility.
PREFFE	Period requisition effectiveness at Subsupply East.
PREFFM	Period requisition effectivenss at Main Supply.
PREFFW	Period requisition effectiveness at Subsupply West.
PRDM	Number of requisitions received at Main Supply per period.
PRISSM	Number requisitions issued on time from Main Supply during a period.
PRP	Procurement reorder point.
PSL	Procurement Safety Level is used in the reorder point computations during the requirements review.
PTC	Total new material and repair costs for a period.
PTNC	Costs for the movement of new material during period from Main Supply to Subsupply East and Subsupply West.

PTRC	Transportation related costs for repairable item movement during a period.

From	To
Subsupply West	Main Supply
Subsupply East	Main Supply
Main Supply	Repair Facility
Repair Facility	Main Supply

PUDM	Total number of units demanded at Main per period.
PUEFFM	Period unit effectiveness at Main Supply.
PUIOTM	Number of units issued on time at Main per period.
QTYTEP TETIM SHIPW TISS SHIPE KOUNT BOT	These symbols are used in the sequential operation of the program and are temporary holding locations.
RCM (I)	A function that generates random numbers that are uniformly distributed between 0 and 1. To activate the random number generator, a 10 digit odd integer for I must be initialized at the beginning of the program.
RCP	Cost to repair a unit in the Repair Facility. This value is expressed as a percentage of the cost of a new item.
REC	Number of units received from contract during a period.
RER	Number of units received from the Repair Facility during a period.
RLT	Repair Lead Time.
RNEWL	Total number of items returned to Main Supply per period that have been determined to be capable of being repaired.

RRP	Repair reorder point.
RSL	Repair Safety Level is used within the reorder point computations during the requirements review.
SCALEB ( )	An array which contains the minimum values of the vertical scales of the graphs. This array will receive its values from TEMPB ( ) or TSCAB ( ) depending on which graph is being plotted.
SCALET ( )	An array which contains the maximum values of the vertical scales of the graphs. This array will receive its values from TEMPT ( ) or TSCAT ( ) depending on which graph is being plotted.
SMWT	Smoothing weight used in the exponential smoothing routine within the demand update routine.
SP1 SP2	The value of the range of the incremental vertical scale values.
SURDE SURDM SURDW	Number of surveys at Subsupply West, at Subsupply East and Main Supply respectively because it was deemed that the carcasses were not capable of being repaired.
SURR	The number of items that are surveyed at the completion of a movement of a lot of repairables through the Repair Facility. It is the result of applying the carcass survival rate to those items completing the repair cycle.
SYM ( )	An array that contains the symbols to be plotted on the graph.
TEMBT ( )	An input array which contains the maximum values for the vertical scales for the cost and reorder point plot routines.
TEMPB ( )	An input array which contains the minimum values for the vertical scales for the cost and reorder point plot routines.

TIEMP	Period total time of all individual outstanding backorders.
TIME	The moving value of time within the program. It is updated each time an event occurs.
TMSW (1)	Lowest value in TNNMW array.
TNNMW ( )	10 position array for transportation times.
QTNMQ ( )	10 position array for transported quantities.
JX1	Index representing TMSW (1) position in TNNMW array.
	The above refers to the time sequencing of shipments of new material from Main Supply to Subsupply West.
TMSW (2)	Lowest value in TNNME array.
TNNME ( )	10 position array for transportation times.
QTNME ( )	10 position array for transported quantities.
JX2	Index representing TMSW (2) position in TNNME array.
	The above refers to the time sequencing of shipments of new material from Main Supply to Subsupply East.
TMSW (3)	Lowest value in TNNCM array.
TNNCM ( )	10 position array for arrival times from procurement.
QTNCM ( )	10 position array for quantities procured.
JX3	Index representing TMSW (3) position in TNNCM array.
	The above refers to the time sequencing of shipments of new material from procurement to Main Supply.
TMSW (4)	Lowest value in TNNFM array.
TNNFM ( )	10 position array for arrival times from Repair.
QTNFM ( )	10 position array for quantities repaired.
JX4	Index representing TMSW (4) position in TNNFM array.
	The above refers to the time sequencing of shipments of new material from Repair Facility to Main Supply.

TMSW (5)	Lowest value in TNRFF array.
TNRFF ( )	10 position array for departure times from Repair.
QTRFF ( )	10 position array for departure quantities.
JX5	Index representing TMSW (5) position in TNRFF array.
	The above refers to the time sequencing of shipment of repaired material completing repair and now ready for shipment to Main Supply.
TMSW (6)	Lowest value in TNRMF array.
TNRMF ( )	10 position array for transportation times.
QTRMF ( )	10 position array for transported quantities.
JX6	Index representing TMSW (6) position in TNRMF array.
	The above refers to the time sequencing of shipments of material to be repaired being shipped from Main Supply to the Repair Facility.
TMSW (7)	Lowest value in TNREM array.
TNREM ( )	10 position array for transportation times.
QTREM ( )	10 position array for transported quantities.
JX7	Index representing TMSW (7) position in TNREM array.
	The above refers to the time sequencing of shipments of failed material being returned from Subsupply East to Main Supply to await repair.
TMSW (8)	Lowest value in TNRWM array.
TNRWM ( )	10 position array for transportation times.
QTRWM ( )	10 position array for transported quantities.
JX8	Index representing TMSW (8) position in TNRWM array.
	The above refers to the time sequencing of shipments of failed material being returned from Subsupply West to Main Supply to await repair.

TMSW (9) TNDLM	TMSW (9) is the value of TNDLM used in switching routine. TNDLM is the time for next demand to be received at Main Supply from local customers.
TMSW (10) TNOWN QTOWN	TMSW (10) is the value of TNOWN used in switching routine. TNOWN is the time the next order for material is demanded at Main Supply from Subsupply West. QTOWN is the corresponding quantity. Only one position is used as the order will be received at Main Supply before another order will be generated.
TMSW (11) TNOEM QTOEM	TMSW (11) is the value of TNOEM used in switching routine. TNOEM is the time the next order for material is demanded at Main Supply from Subsupply East. QTOEM is the corresponding quantity. Only one position is used as the order will be received at Main Supply before another order will be generated.
TMSW (12) TNDEE	TMSW (12) is the value of TNDEE used in switching routine. TNDEE is the time for next demand to be received at East from customers at East.
TMSW (13) TNDWW	TMSW (13) is the value of TNDWW used in switching routine. TNDWW is the time for next demand to be received at West from customers at West.
TMSW (14) TNRR	TMSW (14) is the value of TNRR used in switching routine. TNRR is the time of the next requirements review. The interval is an input value.
TMSW (15) TNPR	TMSW (15) is the value of TNPR used in switching routine. TNPR is the time of next period review. All statistics are collected by period and the value of interval is an input value.

TMSW (16) TNDUP	TMSW (16) is the value of TNDUP used in switching routine. TNDUP is the time of next demand forecasting update. The frequency of updating is an input value.
TMU4	Mean (Days).
SD4	1 Standard Deviation (Days).
UTCR4	Cost to Ship One Unit (Dollars).
A35, A36	Mode of Transportation.
	The above refers to the shipment of failed items from Main Supply to the Repair Facility.
TMU5	Mean (Days).
SD5	1 Standard Deviation (Days).
UTCR5	Cost to Ship One Unit (Dollars).
A25, A26	Mode of Transportation.
	The above refers to the shipment of repaired items from the Repair Facility to Main Supply.
TMU6	Mean (Days).
SD6	1 Standard Deviation (Days).
UTCR6	Cost to Ship One Unit (Dollars).
A33, A34	Mode of Transportation
	The above refers to the shipment of failed items from Subsupply West to Main Supply.
TMU7	Mean (Days).
SD7	1 Standard Deviation (Days).
UTCN7	Cost to Ship One Unit (Dollars).
A27, A28	Mode of Transportation.
	The above refers to the shipment of new items from Main Supply to Subsupply West.
TMU8	Mean (Days).
SD8	1 Standard Deviation (Days).
UTCN8	Cost to Ship One Unit (Dollars).
A29, A30	Mode of Transportation.
	The above refers to the shipment of new items from Main Supply to Subsupply East.
TMU9	Mean (Days).
SD9	1 Standard Deviation (Days).
UTCR9	Cost to Ship One Unit (Dollars).
A31, A32	Mode of Transportation.
	The above refers to the shipment of failed items from Subsupply East to Main Supply.

TMU10 SD10	Mean Repair Time (Days). 1 Standard Deviation (Days). The above refers to the time a failed item will remain in the Repair Facility.
TMU11 SD11	Mean (Months). 1 Standard Deviation (Months). The above refers to the Procurement leadtime variations.
TMU12 SD12	Mean time between demands (Days). 1 Standard Deviation between demands (Days). The above refers to the external demand being introduced at Subsupply East.
TMU13 SD13	Mean time between demands (Days). 1 Standard Deviation between demands (Days). The above refers to the external demand being introduced at Subsupply West.
TMU14 SD14	Mean time between demands (Days). 1 Standard Deviation between demands (Days). The above refers to the external demand being introduced at Main Supply.
TNBO (1,) BOQF (1,)	The arrays store the quantities backordered and the time of backorder establishment for up to 80 different requisitions from Subsupply West.
TNBO (2,) BOQF (2,)	The arrays store the quantities backordered and the time of backorder establishment for up to 80 different requisitions from Subsupply East.
TNBO (3,) BOQF (3,)	The arrays store the quantities backordered and the time of backorder establishment for up to 80 different requisitions from Main Supply and local customers.
TOBOFM	The total number of backorders that are presently recorded at Main Supply. This number is used in the reorder point computations during the requirements review.

TSCAB ( )	An input array which contains the minimum values for the vertical scales for the Main Supply, Subsupply East, Subsupply West plot routines.
TSCAT ( )	An input array which contains the maximum values for the vertical scales for the Main Supply, Subsupply East, Subsupply West plot routines.
UNPRN	The unit price of a new item.
WEIGHT	Weight of the item to be simulated expressed in pounds.
WISS	Number of issues on time at Subsupply West per period.
X (100, 27)	An array that contains the period values that are to be used in the plotting routines for Main Supply, Subsupply East and Subsupply West.
Y (100, 26)	An array that contains the period values that are to be used in the reorder point plot and the cost data plot.
YLOW	The lower limit of the range of the incremental vertical scale values which determines, in conjunction with the upper limit, where a symbol will be plotted on the graph.
YUP	The upper limit of the range of the incremental vertical scale values which determines, in conjunction with the lower limit, where a symbol will be plotted on the graph.

APPENDIX B

REPRODUCTION OF TOTAL FORTRAN PROGRAM

REPAIR PARTS MANAGEMENT SIMULATION

```
C     REPAIR PARTS MANAGEMENT SIMULATION
      INTEGER  BLANK,EYE,SYM
      DIMENSION TNNMW(10),QTNMW(10),TNRWM(10),QTRWM(10),TMSW(16),TNNME(1
     10),QTNME(10),TNREM(10),QTREM(10),TNNFM(10),QTNFM(10),QTNCM(10),
     2TNNCM(10),TNBO(3,80),BOQF(3,80),TNRFF(10),QTRFF(10),TNRMF(10),
     3QTRMF(10),Y(100,26),SYM(20),SCALFT(20),SCALED(20),L(110)
     4,TSCAT(15),TSCAB(15),X(100,27),TEMPT(20),TEMPB(20)
      DATA BLANK,EYE,SYM/1H ,1HI,1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HO,1HP
     1,1HQ,1HR,1HS,1HT,1HU,1HX,1HY,1HZ,1H*,1H./
      READ(5,100)N1,N2,N3,N4,N5,N6,N7,N8,N9,N10
  100 FORMAT(2I10)
      READ(5,109)(TEMPT(IP),TEMPB(IP), IP = 1,20)
      READ(5,110)(TSCAT(IP),TSCAB(IP), IP = 1,15)
      READ(5,101)TMU11,SD11,UNPRN
      READ(5,102) TMU5 , SD5 , UTCR5
      READ(5,102) TMU7 , SD7 , UTCN7
      READ(5,102) TMU8 , SD8 , UTCN8
      READ(5,102) TMU9 , SD9 , UTCR9
      READ(5,102) TMU6 , SD6 , UTCR6
      READ(5,102) TMU4 , SD4 , UTCR4
      READ(5,103) BB , BP , AA , AP , RCP , RLT , TMU10 , SD10
      READ(5,104)TMU12,SD12,TMU13,SD13,TMU14,SD14
      READ(5,111)A1,A2,A3,A4,A21,A22,A37,A38,AJP,A23,A24,A39,A40,AJR
      READ(5,112)A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16,A17,A18,A19,
     1A20
      READ(5,113)KOUNST,KOUNED,CUBE,WEIGHT
      READ(5,114)A25,A26,A27,A28,A29,A30,A31,A32,A33,A34,A35,A36
 1050 CONTINUE
      IF(KOUNST.EQ.KOUNED) STOP
      READ(5,115) I
      READ(5,105) ORDOT , HOCTPR, SHWT , TNRR , TNPR , TNDUP ,PBR
  101 FORMAT(3F10.2)
  102 FORMAT(3F10.2)
  103 FORMAT(8F10.2)
  104 FORMAT(6F10.2)
  105 FORMAT(7F10.2)
  109 FORMAT(2F10.3)
  110 FORMAT(2F10.3)
  111 FORMAT(8A5,F10.2,4A5,F10.2)
  112 FORMAT(16A5)
  113 FORMAT(2I10,2F10.2)
  114 FORMAT(12A5)
  115 FORMAT(I10)
      WRITE(6,60)KOUNST,A1,A2,A3,A4, WEIGHT,CUBE, TMU11, SD11,UNPRN,
     1A21,A22,A37,A38,AJP
   60 FORMAT(1H1//,33X,10HINPUT DATA,
     1/53X,11HTEST NUMBER,I3, 2X,8H(KOUNST),
     2/5X,4HITEM,
     3/8X,14HNOMENCLATURE -,4A5,13H(A1,A2,A3,A4),
     4/8X,18HWEIGHT(PACKAGED) -,F7.2,2X,8H(WEIGHT),
     5/8X,16HCUBE(PACKAGED) -,F6.2,2X,6H(CUBE),
     6/8X,35HPRODUCTION LEADTIME(MEAN IN MONTHS),F6.2,2X,7H(TMU11),
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```
     7/8X,42HPRODUCTION LEADTIME(1 STD. DEV. IN MONTHS),F6.2,2X,6H(SD11)
     8,
     9/8X,24HPROCUREMENT UNIT PRICE -,F8.2,2X,7H(UNPRN),
     1/8X,26HPROCUREMENT SAFETY LEVEL -,4A5,5H(PSL),
     2/8X,35HPROCUREMENT SAFETY LEVEL ADJUSTMENT,F6.2,2X,5H(AJP),)
      WRITE(6,61)A5,A6,A7,A8,A9,A10,A11,A12,A13,A14,A15,A16,A17,A18,A19,
     1A20,TMU5,SD5,UTCR5,A25,A26,TMU7,SD7,UTCN7,A27,A28,TMU8,SD8,UTCN8,
     2A29,A30,TMU9,SD9,UTCR9,A31,A32,TMU6,SD6,UTCR6,A33,A34,TMU4,SD4,
     3UTCR4,A35,A36
   61 FORMAT(5X,19HSYSTEM DISCRIPTION,,
     1/8X,31HLOCATIONS,   MAIN SUPPLY      -,4A5,13H(A5,A6,A7,A8),
     2/21X,17HSUB SUPPLY WEST -,4A5,16H(A9,A10,A11,A12),
     3/21X,17HSUB SUPPLY EAST -,4A5,17H(A13,A14,A15,A16),
     4/21X,17HREPAIR FACILITY -,4A5,17H(A17,A18,A19,A20),
     5/14X,22HNEW MATERIAL MOVEMENTS,/6X,68HFROM        TO     MEAN(DAYS)
     6    1STD DEV          COST             TRANS,/6X,13HREPAIR    MAIN,F6.2
     7,10H /(TMU5)  ,F6.2, 8H /(SD5),F7.2,  9H /(UTCR5),4X,2A5,/6X,13HMA
     8IN     WEST,F5.2,10H /(TMU7)  ,F6.2, 8H /(SD7) ,F7.2, 9H /(UTCN7),
     94X,2A5,/6X,13HMAIN     EAST,F6.2,10H /(TMU8)  ,F6.2, 8H /(SD8) ,F7
     1.2, 9H /(UTCN8),4X,2A5,/14X,29HREPAIRABLE MATERIAL MOVEMENTS,
     2/6X,13HEAST     MAIN,F6.2,10H /(TMU9)  ,F6.2, 8H /(SD9) ,F7.2, 9H
     3/(UTCR9),4X,2A5,/6X,13HWEST     MAIN,F6.2,10H /(TMU6)  ,F6.2, 8H /
     4(SD6) ,F7.2, 9H /(UTCR6),4X,2A5,/6X,13HMAIN    REPAIR,F6.2,10H /(TM
     5U4)  ,F6.2, 8H /(SD4) ,F7.2, 9H /(UTCR4),4X,2A5,/)
      WRITE(6,62)BR,BP,AA,AP,RCP,TMU10,SD10,PLT,A23,A24,A39,A40,AJR
   62 FORMAT(5X,11HREPAIR DATA,
     1/8X,36HACTUAL PERCENT RETURNED FOR REPAIR -,F5.2,2X,4H(BR),
     2/8X,39HPREDICTED PERCENT RETURNED FOR REPAIR -,F5.2,2X,4H(BP),
     3/8X,33HACTUAL PERCENT SURVIVING REPAIR -,F5.2,2X,4H(AA),
     4/8X,36HPREDICTED PERCENT SURVIVING REPAIR -,F5.2,2X,4H(AP),
     5/8X,45HCOST TO REPAIR(PERCENT OF COST OF NEW ITEM) -,F5.2,2X,5H(RC
     6P),/8X,29HMEAN TIME IN DAYS TO REPAIR -,F7.2,2X,6H(SD10),
     7/8X,39HONE STANDARD DEVIATION IN REPAIR TIME -,F5.2,2X,6H(SD10),
     8/8X,47HREPAIR LEADTIME(MEAN IN REPAIR + TMU5 + TMU4) -,F6.2, 5H(PL
     9T),/3X,21HREPAIR SAFETY LEVEL -,4A5,5H(RSL),
     1/8X,30HREPAIR SAFETY LEVEL ADJUSTMENT,F6.2,2X,5H(AJR),)
      WRITE(6,63)TMU12,SD12,TMU13,SD13,TMU14,SD14,ORDCT,HOCTPR,SMWT,
     1TNRR,TNPR,TNDUP,PBR,I
   63 FORMAT(5X,11HDEMAND DATA,
     1/8X,6HEAST =,F7.3,2X,32HMEAN TIME BETWEEN DEMANDS(TMU12),
     2/14X,F7.3,2X,41H1 STD. DEV. IN DAYS BETWEEN DEMANDS(SD12),
     3/8X,6HEAST =,F7.3,2X,32HMEAN TIME BETWEEN DEMANDS(TMU13),
     4/14X,F7.3,2X,41H1 STD. DEV. IN DAYS BETWEEN DEMANDS(SD13),
     5/8X,6HEAST =,F7.3,2X,32HMEAN TIME BETWEEN DEMANDS(TMU14),
     6/14X,F7.3,2X,41H1 STD. DEV. IN DAYS BETWEEN DEMANDS(SD14),
     7//5X,17HSYSTEM PARAMETERS,
     8/8X,15HCOST TO ORDER -,F8.2,2X,7H(ORDCT),
     9/8X,35HCOST TO HOLD(PERCENT OF UNIT PRICE),F6.3,2X,8H(HOCTPR),
     1/8X,25HDEMAND SMOOTHING WEIGHT -,F6.2,2X,6H(SMWT),
     2/8X,25HREQUIREMENTS REVIEW EVERY,F5.0,2X,10HDAYS(TNRR),
     3/8X,19HPERIOD REVIEW EVERY,F5.0,2X,10HDAYS(TNPR),
     4/8X,32HMAIN SUPPLY DEMAND UPDATED EVERY,F5.0,2X,11HDAYS(TNDUP),
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     5/8X,22HSIMULATION RECORDS FOR,F7.0,2X,12HPERIODS(PBR),
     6/8X,43HTHE LAST 100 PERIODS ARE DISPLAYED ON PLOTS.
     7/8X,44HRANDOM NUMBER GENERATOR INITIALIZED VALUE(I),I12)
      WRITE(6,1071)
 1071 FORMAT(1H1,2X, 91H*PERIOD* CREFFM * CUEFFM * CREFFW * CREFFE *   A
     1RC    *   ANUC   *   ATNC   *   ATRC   *    ATC    *,)
      KOUNST = KOUNST + 1
      HOCTR = (HOCTPR*UNPRN)/100.
      AMODW = 30. /TMU13
      AMODE = 30./TMU12
      DEMFOR = 30./TMU12 + 30./TMU13 + 30./TMU14
      NOHE = 2.0 *AMODE
      OHE = NOHE
       NOHW = 2.0 * AMODW
      OHW = NOHW
      PLT = TMU11
        NOHM = (30./TMU12 + 30./TMU13 + 30./ TMU14 )*TMU11
      OHM = NOHM
      PSL = DEMFOR *(TNRR / 30.0) * AJP
      PSL = DEMFOR *(TNRR / 30.0) * AJP
      J = 0
      TA = 0.0
      CTIEMP = 0.0
      CPTRC = 0.0
      REC = 0.0
      PER = 0.0
      PTRC  = 0.0
      CPTNC = 0.0
      PTNC = 0.0
      CPNUC = 0.0
      ANUC = 0.0
      PNUC = 0.0
      CAPC  = 0.0
      ARC = 0.0
      PRC = 0.0
      PRDM = 0.0
      PRISSM = 0.0
      CRISSM = 0.0
       CPRDM = 0.0
      CUIOTM = 0.0
      CPUDM = 0.0
      CWISS = 0.0
      CEISS = 0.0
      CCURDE = 0.0
      CCURDW = 0.0
      CAWS = 0.0
      PAWS = 0.0
      WISS = 0.0
      EISS = 0.0
      PNEWL = 0.0
      POFW = 0.0
      NPER = 0
```

```
      SURDW = 0.0
      KT = 0
      ROFE = 0.0
      SURDE = 0.0
      DUFC = 0.0
      DUFR = 0.0
      TOROFM = 0.0
      SURDM = 0.0
      OHMR = 0.0
      SURR = 0.0
      TBFM = 0.0
      CURDEM = 0.0
      CURDME = 0.0
      CURDMW = 0.0
      PUDM = 0.0
      PUIOTM = 0.0
      TNOWM = 999999.9
      QTOWM = 0.0
      TNOEM = 0.0
      QTOEM = 0.0
      TNOEM = 0.0
      QTOEM = 0.0
      CURDE = 0.0
      DUEE = 0.0
      DUFW = 0.0
      CURDW = 0.0
      TIME = 0.0
      T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD14+TMU14
      TNDLM = T
      TMSW(9) = TNDLM
      T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD12+TMU12
      TNDEE = T
      TMSW(12) = TNDEE
      T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD13+TMU13
      TNDWW = T
      TMSW(13) = TNDWW
      TMSW(14) = TNRR
      TMSW(15) = TNPR
      TMSW(16) = TNDUP
      DO 1   NP = 1,10
      TNNMW(NP) = 999999.9
      QTNMW(NP) = 0.0
      TNRWM(NP) = 999999.9
      QTRWM(NP) = 0.0
      TNNME(NP) = 999999.9
      QTNME(NP) = 0.0
      TNREM(NP) = 999999.9
      QTREM(NP) = 0.0
      TNNFM(NP) = 999999.9
      QTNFM(NP) = 0.0
      TNNCM(NP) = 999999.9
      QTNCM(NP) = 0.0
```

```
      TNRFF(NP) = 999999.9
      QTRFF(NP) = 0.0
      TNRMF(NP) = 999999.9
      QTRMF(NP) = 0.0
    1 CONTINUE
      DO 2 NP = 1,8
      TMSW(NP) = 999999.9
    2 CONTINUE
      TMSW(10) = 999999.9
      TMSW(11) = 999999.9
      DO  3  JA = 1,3
      DO  3  JB = 1,80
      TNBO(JA,JB) = 999999.9
      BOQF(JA,JB) = 0.0
    3 CONTINUE
C
C
C  EVENT ** SWITCHING ROUTINE TO FIND LOWEST TIME
C
C
  151 CONTINUE
      JA = 1
      XX = TMSW(1)
      DO 153 NP = 2,16
      IF((XX-TMSW(NP)).GE.0.0) GO TO 152
      GO TO 153
  152 XX = TMSW(NP)
      JA = NP
  153 CONTINUE
      IF(JA.EQ.1) GO TO 201
      IF(JA.EQ.2) GO TO 251
      IF(JA.EQ.3) GO TO 301
      IF(JA.EQ.4) GO TO 301
      IF(JA.EQ.5) GO TO 401
      IF(JA.EQ.6) GO TO 451
      IF(JA.EQ.7) GO TO 501
      IF(JA.EQ.8) GO TO 551
      IF(JA.EQ.9) GO TO 601
      IF(JA.EQ.10) GO TO 651
      IF(JA.EQ.11) GO TO 701
      IF(JA.EQ.12) GO TO 751
      IF(JA.EQ.13) GO TO 801
      IF(JA.EQ.14) GO TO 851
      IF(JA.EQ.15) GO TO 901
      IF(JA.EQ.16) GO TO 951
C
C
C  EVENT ** TIME NEXT SHIPMENT(NEW) FROM MAIN TO SUB SUPPLY WEST
C
C
  201 CONTINUE
      TIME = TMSW(1)
```

```
      KOUNT = 0
      DUEW = DUEW - QTNMW(JX1)
      OHW = OHW + QTNMW(JX1)
      PTNC  = PTNC + UTCN7 * QTNMW(JX1)
      TNNMW(JX1) = 999999.9
      QTNMW(JX1) = 0.0
      IF(BOFW.LE.0.0) GO TO 210
      IF(OHW.GE.BOFW) GO TO 202
      BOFW = BOFW - OHW
      SELT = OHW
      OHW = 0.0
      GO TO 203
  202 SELT = BOFW
      OHW = OHW - BOFW
      BOFW = 0.0
  203 CONTINUE
      NELT = SELT
      IF(NELT.LE.0) GOTO 213
      DO 205 NQ = 1,NELT
      IF(RCM(I).GT.BB) GO TO 204
      KOUNT = KOUNT + 1
      GO TO 205
  204 SURDW = SURDW + 1.0
  205 CONTINUE
      DO 207 NQ = 1,10
      IF(QTRWM(NQ).EQ.0.0) GO TO 206
  207 CONTINUE
  206 QTRWM(NQ) = KOUNT
      T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD6+TMU6
      TNRWM(NQ) = TIME + T
      JX8 = 1
      XY = TNRWM(1)
      DO 209 NP = 1,10
      IF((XY - TNRWM(NP)).GE.0.0) GO TO 208
      GO TO 209
  208 XY = TNRWM(NP)
      JX8 = NP
  209 CONTINUE
      TMSW(8) = TNRWM(JX8)
  210 CONTINUE
  213 CONTINUE
      JX1 = 1
      XY = TNNMW(1)
      DO 212 NP = 1,10
      IF((XY- TNNMW(NP)).GE.0.0) GO TO 211
      GO TO 212
  211 XY = TNNMW(NP)
      JX1 = NP
  212 CONTINUE
      TMSW(1) = TNNMW(JX1)
      GO TO 151
C
```

```
C
C  EVENT ** TIME NEXT SHIPMENT(NEW) FROM MAIN TO SUB SUPPLY EAST
C
C
 251   CONTINUE
       TIME = TMSW(2)
       KOUNT = 0
       DUEE = DUEE - QTNME(JX2)
       OHE = OHE + QTNME(JX2)
       PTNC  = PTNC + UTCN8 * QTNMW(JX2)
       TNNME(JX2) = 999999.9
       QTNME(JX2) = 0.0
       IF(BOFE.LE.0.0) GO TO 260
       IF(OHE.GE.BOFE) GO TO 252
       BOFE = BOFE - OHE
       SELT = OHE
       OHE = 0.0
       GO TO 253
 252   SELT = BOFE
       OHE = OHE - BOFE
       BOFE = 0.0
 253   CONTINUE
       NELT = SELT
       IF(NELT.LE.0) GO TO 263
       DO 255 NO = 1,NELT
       IF(RCM(I).GT.BB) GO TO 254
       KOUNT = KOUNT + 1
       GO TO 255
 254   SURDE = SURDE + 1.0
 255   CONTINUE
       DO 257 NO = 1,10
       IF(QTREM(NO).EQ.0.0) GO TO 256
 257   CONTINUE
 256   QTREM(NO) = KOUNT
       T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD9+TMU9
       TNREM(NO) = TIME + T
       JX7 = 1
       XY = TNREM(1)
       DO 259 NP = 1,10
       IF((XY-TNREM(NP)).GE.0.0) GO TO 258
       GO TO 259
 258   XY = TNREM(NP)
       JX7 = NP
 259   CONTINUE
       TMSW(7) = TNREM(JX7)
 260   CONTINUE
  263  CONTINUE
       JX2 = 1
       XY = TNNME(1)
       DO 262 NP = 1,10
       IF((XY - TNNME(NP)).GE.0.0) GO TO 261
       GO TO 262
```

```
261   XY = TNNME(NP)
      JX2 = NP
262   CONTINUE
      TMSW(2) = TNNME(JX2)
      GO TO 151
C
C
C  ** TIME NEXT SHIPMENT(NEW) FROM CONTRACT TO MAIN SUPPLY
C  ** TIME NEXT SHIPMENT(NEW) FROM REPAIR FACILITY TO MAIN SUPPLY
C
C
301   CONTINUE
      IF(TMSW(3).LT.TMSW(4)) GO TO 302
      TIME = TMSW(4)
      OHM = OHM + QTNFM(JX4)
      RER = RER + QTNFM(JX4)
      DUFR = DUFR - QTNFM(JX4)
      PTRC  = PTRC + UTCRS * QTNFM(JX4)
      QTNFM(JX4) = 0.0
      TNNFM(JX4)= 999999.9
      GO TO 303
302   TIME = TMSW(3)
      REC = REC + QTNCM(JX3)
      OHM = OHM + QTNCM(JX3)
      DUFC = DUFC - QTNCM(JX3)
      PNUC = PNUC + ((UNPRN * QTNCM(JX3)) + ORDCY )
      QTNCM(JX3) = 0.0
      TNNCM(JX3) = 999999.9
303   CONTINUE
      JA = 1
      JB = 1
      XY = TNBO(1,1)
      DO 304 NP = 1,3
      DO 304 NO = 1,80
      IF((XY- TNBO(NP,NO)).LT.0.0) GO TO 304
      XY = TNBO(NP,NO)
      JA = NP
      JB = NO
304   CONTINUE
      IF(BOQF(JA,JB).LE.0.0) GO TO 315
      IF(OHM.LE.0.0) GO TO 315
      IF(JA.EQ.3) GO TO 324
      IF(OHM.GE.BOQF(JA,JB)) GO TO 305
      BOQF(JA,JB) = BOQF(JA,JB) - OHM
      IF(BOQF(JA,JB).LE.0.0)TNBO  (JA,JB) = 999999.0
      TISS = OHM
      TOBOFM = TOBOFM - OHM
      OHM = 0.0
      GO TO 306
305   TOBOFM = TOBOFM - BOQF(JA,JB)
      OHM = OHM - BOQF(JA,JB)
      TISS = BOQF(JA,JB)
```

```
            TNBO(JA,JB) = 999999.9
            BOOF(JA,JB) = 0.0
      306   CONTINUE
            IF(JA.EQ.2) GO TO 312
            DO 308 NP = 1,10
            IF(QTNMW(NP).EQ.0.0) GO TO 307
      308   CONTINUE
      307   QTNMW(NP) = TISS
            TISS = 0.0
            T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD7+TMU7
            TNNMW(NP) = TIME + T
            GO TO 303
      309   KOUNT = 0
            DO 311 NO = 1,NELT
            IF(RCM(I).GT.BB) GO TO 310
            KOUNT = KOUNT + 1
            GO TO 311
      310   SURDM = SURDM + 1.0
            GO TO 329
      311   CONTINUE
            RNEWL = RNEWL + 1.0
            SKOUNT = KOUNT
            OHMR = OHMR + SKOUNT
      329   GO TO 303
      312   DO 313 NP = 1,10
            IF(QTNME(NP).EQ.0.0) GO TO 314
      313   CONTINUE
      314   QTNME(NP) = TISS
            TISS = 0.0
            T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD8+TMU8
            TNNME(NP) = TIME + T
            GO TO 303
      315   JX4 = 1
            XY = TNNFM(1)
            DO 317 NP = 1,10
            IF((XY-TNNFM(NP)).GE.0.0) GO TO 316
            GO TO 317
      316   XY = TNNFM(NP)
            JX4 = NP
      317   CONTINUE
            TMSW(4) = TNNFM(JX4)
            JX1 = 1
            XY = TNNMW(1)
            DO 319 NP = 1,10
            IF((XY-TNNMW(NP)).GE.0.0) GO TO 318
            GO TO 319
      318   XY = TNNMW(NP)
            JX1 = NP
      319   CONTINUE
            TMSW(1) = TNNMW(JX1)
            JX2 = 1
            XY = TNNME(1)
```

```
      DO 321 NP = 1,10
      IF((XY-TNNME(NP)).GE.0.0) GO TO 320
      GO TO 321
  320 XY = TNNME(NP)
      JX2 = NP
  321 CONTINUE
      TMSW(2) = TNNME(JX2)
      JX3 = 1
      XY = TNNCM(1)
      DO 323 NP = 1,10
      IF((XY-TNNCM(NP)).GE.0.0) GO TO 322
      GO TO 323
  322 XY = TNNCM(NP)
      JX3 = NP
  323 CONTINUE
      TMSW(3) = TNNCM(JX3)
      GO TO 151
  324 IF(OHM.GE.BOOF(JA,JB)) GO TO 327
      BOOF(JA,JB) = BOOF(JA,JB) - OHM
      IF(BOOF(JA,JB).LE.0.0)TNBO  (JA,JB) = 999999.0
      TISS = OHM
      TOBOFM = TOBOFM - OHM
      OHM = 0.0
      NELT = TISS
      KOUNT = 0
      DO 326 NQ = 1,NELT
      IF(RCN(I).GT.BB) GO TO 325
      KOUNT = KOUNT + 1
      GO TO 326
  325 SURDM = SURDM + 1.0
      GO TO 328
  326 CONTINUE
      RNEWL = RNEWL + 1.0
      SKOUNT = KOUNT
      OHMR = OHMR + SKOUNT
  328 GO TO 315
  327 TOBOFM = TOBOFM - BOOF(JA,JB)
      OHM = OHM - BOOF(JA,JB)
      TNBO(JA,JB) = 999999.9
      NELT = BOOF(JA,JB)
      BOOF(JA,JB) = 0.0
      GO TO 309
C
C
C  EVENT ** TIME NEXT SHIPMENT EXITS REPAIR FACILITY
C
C
  401 CONTINUE
      TIME = TMSW(5)
      TNREF(JX5) = 999999.9
      NTEMP = QTREF(JX5)
      QTREF(JX5) = 0.0
```

```
      KOUNT = 0.0
      DO 403 NP = 1,NTEMP
      XY = RCM(1)
      IF(XY.GT.AA) GO TO 402
      KOUNT = KOUNT + 1
      GO TO 403
  402 SURR = SURR + 1.0
      DUFR = DUFR - 1.0
  403 CONTINUE
      IF(KOUNT.EQ.0) GO TO 410
      DO 405 NP = 1,10
      IF(QTNFM(NP).EQ.0.0) GO TO 404
  405 CONTINUE
  404 QTNFM(NP) = KOUNT
      PRC = PRC + UNPRN * RCP * QTNFM(NP)
      KOUNT = 0
      T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD5+TMU5
      TNNFM(NP) = TIME + T
      JX4 = 1
      XY = TNNFM(1)
      DO 407 NP = 1,10
      IF((XY-TNNFM(NP)).GE.0.0) GO TO 406
      GO TO 407
  406 XY = TNNFM(NP)
      JX4 = NP
  407 CONTINUE
      TMSW(4) = TNNFM(JX4)
  410 CONTINUE
      JX5 = 1
      XY = TNRFF(1)
      DO 409 NP = 1,10
      IF((XY-TNRFF(NP)).GE.0.0) GO TO 408
      GO TO 409
  408 XY = TNRFF(NP)
      JX5 = NP
  409 CONTINUE
      TMSW(5) = TNRFF(JX5)
      GO TO 151
  151 CONTINUE
C
C
C  EVENT ** TIME NEXT RECEIPT AT REPAIR FACILITY
C
C
      TIME = TMSW(6)
      PTRC  = PTRC + UTCR4 * QTRMF(JX6)
      QTT = QTRMF(JX6)
      QTRMF(JX6) = 0.0
      TNRMF(JX6) = 999999.9
      JX6 = 1
      XY = TNRMF(1)
      DO 453 NP = 1,10
```

```
      IF((XY-TNRMF(NP)).GE.0.0) GO TO 452
      GO TO 453
452   XY = TNRMF(NP)
      JX6 = NP
453   CONTINUE
      TMSW(6) = TNRMF(JX6)
      DO 454 NP = 1,10
      IF(QTRFF(NP).EQ.0.0) GO TO 455
454   CONTINUE
455   QTRFF(NP) = QTT
      T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD10+TMU10
      TNRFF(NP) = TIME + T
      JX5 = 1
      XY = TNRFF(1)
      DO 457 NP = 1,10
      IF((XY-TNRFF(NP)).GE.0.0) GO TO 456
      GO TO 457
456   XY = TNRFF(NP)
      JX5 = NP
457   CONTINUE
      TMSW(5) = TNRFF(JX5)
      GO TO 151
C
C  EVENT  ** TIME NEXT SHIPMENT(REPAIRABLE) FROM SUB SUPPLY EAST AT MAIN
C
C
501   CONTINUE
      TIME = TMSW(7)
      CHMR = CHMR + QTREM(JX7)
      RNEWL = RNEWL + QTREM(JX7)
      PTRC  = PTRC + UTCP9 * QTREM(JX7)
      QTREM(JX7) = 0.0
      TNREM(JX7) = 999999.0
      JX7 = 1
      XY = TNREM(1)
      DO 503 NP = 1,10
      IF((XY-TNREM(NP)).GE.0.0) GO TO 502
      GO TO 503
502   XY = TNREM(NP)
      JX7 = NP
503   CONTINUE
      TMSW(7) = TNREM(JX7)
      GO TO 151
C
C
C  EVENT ** TIME NEXT SHIPMENT(REPAIRABLE) FROM SUB SUPPLY WEST AT MAIN
C
C
551   CONTINUE
      TIME = TMSW(8)
      CHMR = CHMR + QTRWM(JX8)
      RNEWL = RNEWL+QTRWM(JX8)
```

```
                PTRC  = PTRC + UTCP6 * QTRWM(JX8)
            QTRWM(JX8) = 0.0
            TNRWM(JX8) = 999999.9
            JX8 = 1
            XY = TNRWM(1)
            DO 553 NP = 1,10
            IF((XY-TNRWM(NP)).GE.0.0) GO TO 552
            GO TO 553
      552   XY = TNRWM(NP)
            JX8 = NP
      553   CONTINUE
            TMSW(6) = TNRWM(JX8)
            GO TO 151
      C
      C
      C  EVENT ** TIME NEXT DEMAND MAIN SUPPLY POINT(LOCAL)
      C
      C
      601   CONTINUE
            TIME = TNDLM
            CURDEM = CURDEM + 1.0
            PRDM = PRDM + 1.0
            PUDM = PUDM + 1.0
            IF(OHM.GE.1.0) GO TO 604
            DO 603 NQ = 1,80
            IF(BOOF(3,NQ).EQ.0.0) GO TO 602
      603   CONTINUE
      602   BOOF(3,NQ) = 1.0
            TNBO(3,NQ) = TIME
            TOBOFM = TOBOFM + 1.0
            GO TO 606
      604   CONTINUE
            PRISSM = PRISSM + 1.0
            PUIOTM = PUIOTM + 1.0
            OHM = OHM - 1.0
            XY = RCM(I)
            IF(XY.GT.BB) GO TO 605
            OHMR = OHMR + 1.0
            RNEWL = RNEWL + 1.0
            GO TO 606
      605   SURDM = SURDM + 1.0
      606   CONTINUE
            T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD14+TMU14
            TNDLM = TIME + T
            TMSW(9) = TNDLM
            GO TO 151
      C
      C
      C  EVENT ** TIME NEXT DEMAND FROM SUB SUPPLY WEST AT MAIN SUPPLY POINT
      C
      C
      651   CONTINUE
```

REPAIR PARTS MANAGEMENT SIMULATION

```
      TIME = TNOWM
      TNOWM = 999999.9
      TMSW(10) = 999999.9
      CURDEM = CURDEM + QTOWM
      PRDM = PRDM + 1.0
      PUDM = PUDM + QTOWM
      IF(OHM.GT.0.0) GO TO 652
      BOT = QTOWM
      GO TO 653
  652 IF(OHM.GE.QTOWM) GO TO 656
      PRDM = PRDM + 1.0
      PRISSM = PRISSM + 1.0
      PUIOTM = PUIOTM + OHM
      BOT = QTOWM - OHM
      SHIPW = OHM
      QTOWM = 0.0
  653 CONTINUE
      OHM = 0.0
      TOBOFM = TOBOFM + BOT
      DO 654 NQ = 1,80
      IF(BOQF(1,NQ).LT.1.0) GO TO 655
  654 CONTINUE
  655 BOQF(1,NQ) = BOT
      BOT = 0.0
      TNBQ(1,NQ) = TIME
      GO TO 657
  656 OHM = OHM - QTOWM
      PRISSM = PRISSM + 1.0
      SHIPW = QTOWM
      PUIOTM = PUIOTM + QTOWM
      QTOWM = 0.0
  657 CONTINUE
      DO 658 NP = 1,10
      IF(QTNMW(NP).LT.1.0) GO TO 659
  658 CONTINUE
  659 QTNMW(NP) = SHIPW
      SHIPW = 0.0
      T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD7+TMU7
      TNNMW(NP) = TIME + T
      JX1 = 1
      XY = TNNMW(1)
      DO 661 NQ = 1,10
      IF((XY-TNNMW(NQ)).GE.0.0) GO TO 660
      GO TO 661
  660 XY = TNNMW(NQ)
      JX1 = NQ
  661 CONTINUE
      TMSW(1) = TNNMW(JX1)
      GO TO 151
C
C
C  EVENT ** TIME NEXT DEMAND FROM SUB SUPPLY EAST AT MAIN SUPPLY POINT
```

```
      C
      C
  701   CONTINUE
        TIME = TNOEM
        TNOEM = 999999.9
        TMSW(11) = 999999.9
        CURDEM = CURDEM + OTOEM
        PRDM = PRDM + 1.0
        PUDM = PUDM + OTOEM
        IF(OHM.GT.0.0) GO TO 702
        BOT = OTOEM
        GO TO 703
  702   IF(OHM.GE.OTOEM) GO TO 706
        PUIOTM = PUIOTM + OHM
        PRDM = PRDM + 1.0
        PRISSM = PRISSM + 1.0
        BOT = OTOEM - OHM
        SHIPE = OHM
        OHM = 0.0
        OTOEM = 0.0
  703   CONTINUE
        TOBOEM = TOBOEM + BOT
        DO 704 NO = 1,80
        IF(BOOF(2,NO).LT.1.0) GO TO 705
  704   CONTINUE
  705   BOOF(2,NO) = BOT
        BOT = 0.0
        TNBO(2,NO) = TIME
        GO TO 707
  706   CONTINUE
        PRISSM = PRISSM + 1.0
        PUIOTM = PUIOTM + OTOEM
        OHM = OHM - OTOEM
        SHIPE = OTOEM
        OTOEM = 0.0
  707   CONTINUE
        DO 708 NP = 1,10
        IF(QTNME(NP).LT.1.0) GO TO 709
  708   CONTINUE
  709   QTNME(NP) = SHIPE
        SHIPE = 0.0
        T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SDR+TMUB
        TNNME(NP) = TIME + T
        JX2 = 1
        XY = TNNME(1)
        DO 711 NO = 1,10
        IF((XY-TNNME(NO)).GE.0.0) GO TO 710
        GO TO 711
  710   XY = TNNME(NO)
        JX2 = NO
  711   CONTINUE
        TMSW(2) = TNNME(JX2)
```

```
            GO TO 151
      C
      C
      C  EVENT ** TIME NEXT DEMAND FROM EAST AT SUB SUPPLY EAST
      C
      C
      751   CONTINUE
            TIME = TMSW(12)
            CURDE = CURDE + 1.0
            CURDME = CURDME + 1.0
            IF(OHE.GE.1.0) GO TO 752
            BOFE = BOFE + 1.0
            GO TO 759
      752   OHE = OHE - 1.0
            EISS = EISS + 1.0
            XY = RCM(I)
            IF(XY.GT.BB) GO TO 755
            DO 753 NP = 1,10
            IF(QTREM(NP).EQ.0.0) GO TO 754
      753   CONTINUE
      754   QTREM(NP) = 1.0
            T = ((-2.0*ALOG(RCM(I))),**.5*COS(6.283*RCM(I)))*SD9+TMU9
            TNREM(NP) = TIME + T
            IF(TNREM(NP).LT.TMSW(7)) GO TO 756
            GO TO 759
      755   SURDE = SURDE + 1.0
            GO TO 759
      756   JX7 = 1
            XY = TNREM(1)
            DO 758 NP = 1,10
            IF((XY-TNREM(NP)).GE.0.0) GO TO 757
            GO TO 758
      757   XY = TNREM(NP)
            JX7 = NP
      758   CONTINUE
            TMSW(7) = TNREM(JX7)
      759   CONTINUE
            T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD12+TMU12
            TNDEE = TIME + T
            TMSW(12) = TNDEE
            ROMTE = 2.0 *AMODE + BOFF
            IF((OHE + DUEE).GT.ROMTE)  GO TO 760
            NQTOEM = ROMTE -(OHE + DUEE) + AMODE
            QTOEM = NQTOEM
            TNOEM = TIME + 1.0
            DUEE = DUEE + QTOEM
            TMSW(11) = TNOEM
      760   CONTINUE
            GO TO 151
      C
      C  EVENT ** TIME NEXT DEMAND FROM WEST AT SUB SUPPLY WEST
      C
```

```
C
801    CONTINUE
       TIME = TMSW(13)
       CURDW = CURDW + 1.0
        CURDMW = CURDMW + 1.0
       IF(OHW.GE.1.0) GO TO 802
       BOFW = BOFW + 1.0
       GO TO 809
802    OHW = OHW - 1.0
       WISS = WISS + 1.0
       XY = RCM(I)
       IF(XY.GT.BB) GO TO 805
       DO 803 NP = 1,10
       IF(QTRWM(NP).EQ.0.0) GO TO 804
803    CONTINUE
804    QTRWM(NP) = 1.0
       T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD6+TMU6
       TNRWM(NP) = TIME + T
       IF(TNRWM(NP).LT.TMSW(8)) GO TO 806
       GO TO 809
805    SURDW = SURDW + 1.0
       GO TO 809
806    JX8 = 1
       XY = TNRWM(1)
       DO 808 NP = 1,10
       IF((XY-TNRWM(NP)).GE.0.0) GO TO 807
       GO TO 808
807    XY = TNRWM(NP)
       JX8 = NP
808    CONTINUE
       TMSW(8) = TNRWM(JX8)
809    CONTINUE
       T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD13+TMU13
       TNDWW = TIME + T
       TMSW(13) = TNDWW
       ROMTW = 2.0 * AMODW + BOFW
      IF((OHW + DUEW).GT.ROMTW) GO TO 810
       NQTOWM = ROMTW -(OHW + DUEW) + AMODW
       QTOWM = NQTOWM
       TNOWM = TIME + 1.0
       DUEW  = DUEW + QTOWM
       TMSW(10) = TNOWM
810    CONTINUE
       GO TO 151
C
C
C  EVENT ** TIME NEXT REQUIREMENTS REVIEW
C
C
851    CONTINUE
       TIME = TMSW(14)
       RRP = RLT * DEMFOR +RSL + TOROFM
```

```
        PRP = PLT + DEMFOR +PSL + TORDFM
        NEOQ = ((24.*ORDCT*DEMFOR*(1.-(AP*BP)))/(UNPRN*HOCTR))**.5 +1.0
        HARDA = DUFR + DUFC + OHM
         MINEOQ = DEMFOR*(1.0-(AP*BP))*3.0
        EXASPP = HARDA+(AP*OHMR)+(AP*BP)*DEMFOR*(PLT-RLT)
        IF(NEOQ.LT.MINEOQ)  GO TO 852
        EOQ = NEOQ
        GO TO 853
 852    EOQ = MINEOQ
 853    CONTINUE
        NREOQ = ((24.*ORDCT*DEMFOR*AP*BP)/(OCP*UNPRN*HOCTR))**.5+1.0
        MINREQ = DEMFOR*AP*BP*2.0
        IF(NREOQ.LT.MINREQ)GO TO 880
        REOQ = NREOQ
        GO TO 882
 880    REOQ = MINREQ
 882     CONTINUE
        IF(EXASPP.GT.PRP) GO TO 862
        DO 854 NP = 1,10
        IF(QTRMF(NP).EQ.0.0) GO TO 855
 854    CONTINUE
 855    QTRMF(NP) = OHMR
        OHMR = 0.0
        IF(QTRMF(NP).EQ.0.0) GO TO 871
        T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD4+TMU4
        TNRMF(NP) = TIME + T
        DUFR = DUFR + QTRMF(NP)
        JX6 = 1
        XY = TNRMF(1)
        DO 857 NP = 1,10
        IF((XY-TNRMF(NP)).GE.0.0) GO TO 856
        GO TO 857
 856    XY = TNRMF(NP)
        JX6 = NP
 857    CONTINUE
        TMSW(6) = TNRMF(JX6)
 871    CONTINUE
        DO 858 NP = 1,10
        IF(QTNCM(NP).EQ.0.0) GO TO 859
 858    CONTINUE
 859    NT = PRP - EXASPP
        AT = NT
        QTNCM(NP) =EOQ + AT
        T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD11+TMU11
        TNNCM(NP) = TIME + (T*30.)
        DUFC = DUFC + QTNCM(NP)
        JX3 = 1
        XY = TNNCM(1)
        DO 861 NP = 1,10
        IF((XY-TNNCM(NP)).GE.0.0) GO TO 860
        GO TO 861
 860    XY = TNNCM(NP)
```

```
      JX3 = NP
  861 CONTINUE
      TMSW(3) = TNNCM(JX3)
      GO TO 869
  862 QTYTEP=0.0
      TETIM = TIME + RLT *30.
      DO 872 NP=1,10
      IF(QTNCM(NP).EQ.0.0) GO TO 872
      IF(TETIM.GT.TNNCM(NP)) GO TO 872
      QTYTEP = QTYTEP + QTNCM(NP)
  872 CONTINUE
      HARDA = HARDA - QTYTEP
      IF(HARDA.LE.RRP) GO TO 863
      GO TO 869
  863 NTEMP = REOQ + (RRP- HARDA)
      TEMP = NTEMP
      IF(OHMR.LT.TEMP) GO TO 864
      QTYTR = TEMP
      OHMR = OHMR - TEMP
      GO TO 870
  864 QTYTR = OHMR
      OHMR = 0.0
  870 CONTINUE
      DO 865 NP = 1,10
      IF(QTRMF(NP).EQ.0.0) GO TO 866
  865 CONTINUE
  866 QTRMF(NP) = QTYTR
      QTYTR = 0.0
      IF(QTRMF(NP).EQ.0.0) GO TO 869
      T = ((-2.0*ALOG(RCM(I)))**.5*COS(6.283*RCM(I)))*SD4+TMU4
      TNRMF(NP) = TIME + T
      DUFR = DUFR + QTRMF(NP)
      JX6 = 1
      XY = TNRMF(1)
      DO 868 NP = 1,10
      IF((XY-TNRMF(NP)).GE.0.0) GO TO 867
      GO TO 868
  867 XY = TNRMF(NP)
      JX6 = NP
  868 CONTINUE
      TMSW(6) = TNRMF(JX6)
  869 CONTINUE
      TMSW(14) = TIME + TNRR
      GO TO 151
C
C
C  EVENT ** TIME NEXT PERIOD REVIEW
C
C
  901 CONTINUE
      TIME = TMSW(15)
      KT = KT + 1
```

```
      IF(KT.LE.25) GO TO 930
      NPER = NPER + 1
      ABC = NPER
      PREFFM = PRISSM / PRDM
      CRISSM = CRISSM + PRISSM
      CPRDM = CPRDM + PRDM
      CREFFM = CRISSM / CPRDM
      PUFFFM = PUIOTM / PUDM
      CUIOTM = CUIOTM + PUIOTM
      CPUDM = CPUDM + PUDM
      CUFFFM = CUIOTM / CPUDM
      PREFFW = WISS / CURDW
      CWISS = CWISS + WISS
      CCURDW = CCURDW + CURDW
      CREFFW = CWISS / CCURDW
      PREFFE = EISS / CURDE
      CEISS = CEISS + EISS
      CCURDE =CCURDE + CURDE
      CREFFE = CEISS / CCURDE
      CARC= CARC + PRC
      ARC   = CARC / ABC
      CPNUC = CPNUC + PNUC
      ANUC  = CPNUC / ABC
      CPTNC = CPTNC + PTNC
      ATNC  = CPTNC /ABC
      CPTRC = CPTRC + PTRC
      ATRC  = CPTRC / ABC
      IF(AA.EQ.0.0) GO TO 907
      GO TO 908
  907 PAWS=PLT*DEMFOR+PSL+.5*EOQ
      GO TO 909
  908 CONTINUE
      PAWS=PLT*(1.-AP*BP)*DEMFOR+PSL+.5*EOQ+(PLT*AP*BP*DEMFOR+RSL+.5*REO
     1Q)
  909 CONTINUE
      CAWS = PAWS + CAWS
      AWS = ( CAWS / ABC ) * UNPRN
      PTC = PRC + PNUC + PTNC + PTRC
      ATC = ARC + ANUC + ATNC + ATRC
      A = 0.0
      DO 906 NP = 1,3
      DO 906 NQ = 1,80
      IF(BOOF(NP,NQ).GE.1.0)GO TO 905
      GO TO 906
  905 A = A+ 1.0
      TBEM = TBEM + BOOF(NP,NQ)
      TIMDIF =TIME - TNBO(NP,NQ)
      TIEMP =TIEMP + TIMDIF
  906 CONTINUE
      TA = TA + A
      CTIEMP = CTIEMP + TIEMP
      IF(TA.EQ.0.0) GO TO 921
```

```
      CAVBOG = CTIEMP / YA
       GO TO 922
 921  CAVBOG = 0.0
  922 CONTINUE
      IF(NPER.NE.(NPER/50)*50) GO TO 910
      WRITE(6,1070)NPER,CREFFM,CUEFFM,CREFFW,CREFFF,ARC,ANUC,ATNC,ATPC,
     1ATC
 1070 FORMAT(1H0,2X,I8,F9.5,F9.5,F9,5,F9.5,F10.2,F9.2,F9.2,F9.2,F10.2)
 910  CONTINUE
      APER = NPER
      IF(APER.LT.PRR) GO TO 930
      J = J + 1
      Y(J, 1) = PREFFM * 100.
      Y(J,2 ) =PUEFFM  * 100.
      Y(J,3 ) = CREFFM * 100.
      Y(J,4 ) = CUFFFM * 100.
      Y(J,5) = TRFM
      Y(J,6 ) = PUDM
      Y(J,7 ) = OHM
      Y(J,8 ) = OHMR
      Y(J,9 ) = PREFFW * 100.
      Y(J,10) = CREFFW * 100.
      Y(J,11) = CURDW
      Y(J,12) =WISS
      Y(J,13) = ROFW
      Y(J,14) = OHW
      Y(J,15) = PREFFE * 100.
      Y(J,16) = CREFFE * 100.
      Y(J,17)= CURCE
      Y(J,18) = EISS
      Y(J,19) = ROFE
      Y(J,20 ) = OHE
      Y(J,21) = SUPR
      Y(J,22) = SURDM
      Y(J,23) = SURDE
      Y(J,24) = SURDW
      Y(J,25) = RNEWL
      Y(J,26) = CAVBOG
      X(J,1) = PSL
      X(J,2) = TOBOFM + PSL
      X(J,3) = TOBOFM + PSL + PLT * DEMFOR
      X(J,4) = RSL
      X(J,5) = RSL + TOBOFM + RLT * DEMFOR
      X(J,6) = OHM
      X(J,7) = OHM + DUFC
      X(J,8) = OHM + DUFC + DUFR
      X(J,9) = OHM + DUFC + DUFR +(AA*OHMR)+(AA*BB)* DEMFOR*(PLT-RLT)
      X(J,10) = ARC
      X(J,11) = ANUC
      X(J,12) = ATNC
      X(J,13) = ATRC
      X(J,14) = ATC
```

```
            X(J,15) = AWS
            X(J,16) = PRC
            X(J,17) = PNUC
            X(J,18) = PTNC
            X(J,19) = PTRC
            X(J,20) = PTC
            X(J,21) = PLT * DEMFOR
            X(J,22) = TOBOFM
            X(J,23) = PLT * DEMFOR
            X(J,24) = DUFC
            X(J,25) = DUFR
            X(J,26) = RER
            X(J,27) =REC
            IF(J.EQ.100) GO TO 1000
      930   CONTINUE
            TBFM = 0.0
            PTRC  = 0.0
            PTNC = 0.0
            PRC = 0.0
            PNUC = 0.0
            PRISSM = 0.0
            WISS =0.0
            EISS = 0.0
            PREM = 0.0
            PUDM = 0.0
            RNEWL = 0.0
            CURDE = 0.0
            CURDW = 0.0
            PUIOTM = 0.0
            PAWS = 0.0
            REC = 0.0
            PER = 0.0
            SURR = 0.0
            SURDE = 0.0
            SURDW = 0.0
            SURDM = 0.0
            TIEMP = 0.0
            TMSW(15) = TIME + TNPR
            GO TO 151
      C
      C
      C  EVENT ** TIME NEXT MAIN SUPPLY POINT DEMAND UPDATE
      C
      C
      951   CONTINUE
            DEMFOR = (1.0-SMWT)* DEMFOR + SMWT* CURDEM
            CURDEM = 0.0
            AMODE = (AMODE + CURDME)/2.0
            AMODW = (AMODW + CURDMW)/2.0
            CURDME = 0.0
            CURDMW = 0.0
            TIME = TMSW(16)
```

```
      YMSW(16) = TIME + TNDUP
      PSL = DEMFOR *(TNRR / 30.0) * AJP
      RSL = DEMFOR *(TNRR / 30.0) * AJR
      GO TO 151
C
C
C  **  PLOT ROUTINES
C
C
 1000 CONTINUE
      DO 1037 NP = 1,20
      SCALET(NP) = TEMPT(NP)
      SCALEB(NP) = TEMPB(NP)
 1037 CONTINUE
      SP1 = (SCALET(N1 )- SCALEB(N 1))/50.0
      SP2 = (SCALET(N2 )- SCALEB(N2 ))/50.0
      NA = 1
      NB = 8
      NZ = 1
      AINSC1 = SCALEB(N1)
      AINSC2 = SCALEB(N2 )
      WRITE(6,1001)
 1001 FORMAT(1H1,52X,24H*** MAIN SUPPLY DATA ***,/1X,
     1130H         * PERIOD EFFECT * CUMULA EFFECT * END PERIOD * PERIOD
     2DEM * ON HAND * ON HAND * REPAIR RETN * AVG AGE OF * SURVY * SURVY
     3 *,/1X,130H PERIOD * REQN ** UNITS * REQN ** UNITS * BACKORDERS *
     4 IN UNITS  *   NEW   * REPAIR  *   PERIOD    * BACKORDERS *  DEM
     5*  REP  *,)
      DO 1002 NP = 1,100
      WRITE(6,1003)NP,Y(NP,1),Y(NP,2),Y(NP,3),Y(NP,4),Y(NP,5),Y(NP,6),
     1Y(NP,7),Y(NP,8),Y(NP,25),Y(NP,26),Y(NP,22),Y(NP,21)
 1002 CONTINUE
 1003 FORMAT(3X,I4,3X,F6.2,2X,F7.2,1X,F6.3,2X,F6.3,4X,F7.3,7X,F7.3,5X,
     1F6.2,3X,F6.2,5X,F8.3,6X,F8.2,3X,F7.2,2X,F5.1)
      WRITE(6,1004)
 1004 FORMAT(1H1,53X,19H   MAIN SUPPLY PLOT,/)
 1005 CONTINUE
      DO  1006  IP = 2,100
      L(IP) = BLANK
 1006 CONTINUE
       L(1) = EYE
      L(101) = EYE
      DO 1013  NL = 1,50
      NLINE = 51 - NL
      DO 1007  M = NA,NB
      YUP= (FLOAT(NLINE))*((SCALET(M)-SCALEB(M))/50.0) + SCALEB(M)
      YLOW=(FLOAT(NLINE)-1.0)*((SCALET(M)-SCALEB(M))/50.0)+SCALEB(M)
      DO 1007  IP = 2,100
      IZ =  IP - 1
      IF(Y(IZ,M).LE.YUP.AND.Y(IZ,M).GT.YLOW) L(IP) = SYM(M)
 1007 CONTINUE
      IF(MOD(NLINE,5).EQ.0) GO TO 1009
```

```
      WRITE(6,1008) (L(IP), IP = 1,101)
 1008 FORMAT(21X,101A1)
      GO TO 1011
 1009 ALINE = NLINE
      S1 = SP1*ALINE +AINSC1
      S2 = SP2 * ALINE +AINSC2
      WRITE(6,1010) S1,(L(IP),IP = 1,101), S2
 1010 FORMAT(6X,F9.3,6X,101A1,F8.1)
 1011 DO 1012  IP = 2,100
      L(IP) = BLANK
 1012 CONTINUE
 1013 CONTINUE
      WRITE(6,1014)
 1014 FORMAT (21X,101HI----+----+----+----+----+----+----+----+----+----
     1+----+----+----+----+----+----+----+----+----+----I/21X,
     29H0         , 10H10       , 10H20       , 10H30       ,
     310H40       , 10H50       , 10H60       , 10H70       ,
     410H80       , 9H90       , 3H100/65X,15H    PERIODS    ,/)
      IF(NZ.EQ.1) GOTO 1015
      IF(NZ.EQ.2) GO TO 1020
      IF(NZ.EQ.3) GO TO 1025
      IF(NZ.EQ.4) GO TO 1030
      IF(NZ.EQ.5) GO TO 1050
 1015 CONTINUE
      NA = 9
      NB = 14
      NZ = 2
      AINSC1 = SCALEB(N3)
      AINSC2 = SCALEB(N4 )
      SP1 = (SCALET(N3 )- SCALEB(N3 ))/50.0
      SP2 = (SCALET(N4 )- SCALEB(N4 ))/50.0
      WRITE(6,1016)
 1016 FORMAT(1H1,54X,23H*** SUB SUPPLY WEST **  ,/1X,
     179 H          *  EFFECTIVENESS  * PERIOD *  ISSUES * END PERIOD * ON
     2 HAND * SURVEYS *,/1X,
     379 H PERIOD * PERIOD * CUMULA * DEMAND * ON TIME * BACKORDERS *
     4NEW   * DEMAND  *,)
      DO 1018 NP = 1,100
      WRITE(6,1017)NP,Y(NP,9),Y(NP,10),Y(NP,11),Y(NP,12),Y(NP,13),
     1Y(NP,14),Y(NP,24)
 1017 FORMAT(3X,I4,3X,F7.3,2X,F7.3,3X,F6.2,3X,F7.2,4X,F6.2,5X,F6.2,3X,
     1F7.2)
 1018 CONTINUE
      WRITE(6,1019)
 1019 FORMAT(1H1,53X,16H SUB SUPPLY WEST,/)
      GO TO 1005
 1020 CONTINUE
      NA = 15
      NB = 20
      NZ = 3
      AINSC1 = SCALEB(N5)
      AINSC2 = SCALEB(N6 )
```

```
       SP1 = (SCALET(N5 )- SCALEB(N5 ))/50.0
       SP2 = (SCALET(N6 )- SCALEB(N6 ))/50.0
       WRITE(6,1021)
 1021  FORMAT(1H1,54X,23H*** SUB SUPPLY EAST ***,/1X,
      179 H         *  EFFECTIVENESS  * PERIOD *  ISSUES * END PERIOD * ON
      2 HAND * SURVEYS *,/1X,
      379 H PERIOD * PERIOD * CUMULA * DEMAND * ON TIME * BACKORDERS *
      4NEW   * DEMAND  *,)
       DO 1023  NP = 1,100
       WRITE(6,1022)NP,Y(NP,15),Y(NP,16),Y(NP,17),Y(NP,18),Y(NP,19),
      1Y(NP,20),Y(NP,23)
 1022  FORMAT(3X,I4,3X,F7.3,2X,F7.3,3X,F6.2,3X,F7.2,4X,F8.2,5X,F6.2,3X,
      1F7.2)
 1023  CONTINUE
       WRITE(6,1024)
 1024  FORMAT(1H1,53X,16H SUB SUPPLY EAST,/)
       GO TO 1005
 1025  CONTINUE
       NA = 1
       NZ = 4
       NB = 9
       DO 1026 IP = 1,15
       SCALET(IP) = TSCAT(IP)
       SCALEB(IP) = TSCAB(IP)
 1026  CONTINUE
       AINSC1 = SCALEB(N7)
       AINSC2 = SCALEB(N8)
       SP1 = (SCALET(N7 )- SCALEB(N7 ))/50.0
       SP2 = (SCALET(N8 )- SCALEB(N8 ))/50.0
       WRITE(6,1027)
 1027  FORMAT(1H1,46X,36H***  REORDER POINT PRESENTATION  ***,/1X,
      1130H         * PROCURMT * BACKORDER * PLT *  * PROCURMT * REPAIR
      2* PLT *  *  REPAIR  *    DUE   *  DUE   * ON HAND *  REC  *  REC
      3 *,/1X,
      4*30H PERIOD * SAFE LEV * FILE MAIN * DEMFOR * REORD PT * SAFE LEV
      5* DEMFOR * REORD PT * CONTRACT * REPAIR *  MAIN   *REPAIR*CONTRA T
      6 *,)
       DO 1029 NP=1,100
       WRITE(6,1028)NP,X(NP,1 ),Y(NP,5),X(NP,21),X(NP,3),X(NP,4 ),X(NP,23
      1),X(NP,5),X(NP,24),X(NP,25),Y(NP,7),Y(NP,26),X(NP,27)
 1028  FORMAT(3X,I4,4X,F7.2,5X,F7.2 4X,F6.2,3X,F7.2,4X,F7.2,2X,F9.2,2X,
      1F7.2,5X,F7.2,3X,F6.2,3X,F7.2,3X,F5.1,3X,F6.2)
 1029  CONTINUE
       DO 1036  NQ = 1,15
       DO 1036 NP = 1,100
       Y(NP,NQ) = X(NP,NQ)
 1036  CONTINUE
       WRITE(6,1034)
 1034  FORMAT(1H1,46X,36H***  REORDER POINT PRESENTATION  ***,/)
       GO TO 1005
 1030  CONTINUE
       NA =10
```

```
      NB =15
      NZ = 5
      AINSC1 = SCALEB(N9)
      AINSC2 = SCALEB(N10)
      SP1 = (SCALET(N9 )- SCALEB(N9 ))/50.0
      SP2 = (SCALET(N10)- SCALEB(N10))/50.0
      WRITE(6,1031)
 1031 FORMAT(1H1,53X,22H***   COST  DATA   ***,/1X,
     1118H          *     REPAIR COST   *  NEW UNIT COST   * TRANS COST NEW
     2   * TRANS COST REPAIR*      TOTAL COST   * INVESTMENT  *,/1X,
     3118H PERIOD * PERIOD * AVERAGE * PERIOD * AVERAGE * PERIOD * AVERA
     4GE * PERIOD * AVERAGE * PERIOD * AVERAGE *     LEVEL     *,)
      DO 1033 NP =1,100
      WRITE(6,1032)NP,X(NP,16),X(NP,10),X(NP,17),X(NP,11),X(NP,18),
     1X(NP,12),X(NP,19),X(NP,13),          X(NP,20),X(NP,14),X(NP,15)
 1032 FORMAT(1X,I4,4X,F8.2,2X,F8.2,1X,F8.2,2X,F8.2,1X,F8.2,2X,F8.2,1X,
     1F8,2,2X,F8.2,1X,F8.2,2X,F8.2,4X,F8.2)
 1033 CONTINUE
      WRITE(6,1035)
 1035 FORMAT(1H1,53X,22H***   COST  DATA   ***,/)
      GO TO 1005
      END
```

APPENDIX C

INPUT DATA VALUES

```
                                INPUT DATA
                                                    TEST NUMBER  1  (KOUNST)
   ITEM
      NOMENCLATURE -  SERVO AMP           (A1,A2,A3,A4)
      WEIGHT(PACKAGED) - 300.00  (WEIGHT)
      CUBE(PACKAGED) - 10.00  (CUBE)
      PRODUCTION LEADTIME(MEAN IN MONTHS) 12.00  (TMU11)
      PRODUCTION LEADTIME(1 STD. DEV. IN MONTHS)  1.00  (SD11)
      PROCUREMENT UNIT PRICE -  200.00  (UNPRN)
      PROCUREMENT SAFETY LEVEL -DEMFOR*(TNRR/30)*AJP(PSL)
      PROCUREMENT SAFETY LEVEL ADJUSTMENT  1.00  (AJP)
   SYSTEM DISCRIPTION,
      LOCATIONS,    MAIN SUPPLY       -NORFOLK,VA             (A5,A6,A7,A8)
                    SUB SUPPLY WEST -PEARL HARBOR            (A9,A10,A11,A12)
                    SUB SUPPLY EAST -SAN PEDRO , CALIF       (A13,A14,A15,A16)
                    REPAIR FACILITY -LONDON                  (A17,A18,A19,A20)
             NEW MATERIAL MOVEMENTS
    FROM       TO     MEAN(DAYS)       1STD DEV           COST             TRANS
    REPAIR    MAIN 26.00 /(TMU5)     3.00 /(SD5),  18.75 /(UTCR5)     SURFACE
    MAIN      WEST 32.00 /(TMU7)     7.00 /(SD7)   22.80 /(UTCN7)     SURFACE
    MAIN      EAST 25.00 /(TMU8)     5.00 /(SD8)   18.00 /(UTCN8)     SURFACE
             REPAIRABLE MATERIAL MOVEMENTS
    EAST      MAIN  2.00 /(TMU9)     1.00 /(SD9)   45.00 /(UTCR9)     AIR
    WEST      MAIN  2.00 /(TMU6)     1.00 /(SD6)   99.00 /(UTCR6)     AIR
    MAIN    REPAIR 26.00 /(TMU4)     3.00 /(SD4)   18.75 /(UTCR4)     SURFACE
   REPAIR DATA
      ACTUAL PERCENT RETURNED FOR REPAIR - 0.90  (BB)
      PREDICTED PERCENT RETURNED FOR REPAIR - 0.90  (BP)
      ACTUAL PERCENT SURVIVING REPAIR - 0.90  (AA)
      PREDICTED PERCENT SURVIVING REPAIR - 0.90  (AP)
      COST TO REPAIR(PERCENT OF COST OF NEW ITEM) - 0.50  (RCP)
      MEAN TIME IN DAYS TO REPAIR - 120.00  (SD10)
      ONE STANDARD DEVIATION IN REPAIR TIME - 30.00  (SD10)
      REPAIR LEADTIME(MEAN IN REPAIR + TMU5 + TMU4) -  6.00(RLT)
      REPAIR SAFETY LEVEL =DEMFOR*(TNRR/30)*AJP(PSL)
      REPAIR SAFETY LEVEL ADJUSTMENT  1.00  (AJR)
   DEMAND DATA
      EAST =  3.000  MEAN TIME BETWEEN DEMANDS(TMU12)
              1.000  1 STD. DEV. IN DAYS BETWEEN DEMANDS(SD12)
      EAST =  3.000  MEAN TIME BETWEEN DEMANDS(TMU13)
              1.000  1 STD. DEV. IN DAYS BETWEEN DEMANDS(SD13)
      EAST =  3.000  MEAN TIME BETWEEN DEMANDS(TMU14)
              1.000  1 STD. DEV. IN DAYS BETWEEN DEMANDS(SD14)

   SYSTEM PARAMETERS
      COST TO ORDER -   25.00  (ORDCT)
      COST TO HOLD(PERCENT OF UNIT PRICE)15.000  (HOCTPR)
      DEMAND SMOOTHING WEIGHT -  0.20  (SMWT)
      REQUIREMENTS REVIEW EVERY  30.  DAYS(TNRR)
      PERIOD REVIEW EVERY  10.  DAYS(TNPR)
      MAIN SUPPLY DEMAND UPDATED EVERY  30.  DAYS(TNDUP)
      SIMULATION RECORDS FOR  1500.  PERIODS(PRR)
      THE LAST 100 PERIODS ARE DISPLAYED ON PLOTS
      RANDOM NUMBER GENERATOR INITIALIZED VALUE(I)  1234567803
```

APPENDIX D

SAMPLE OF TYPICAL OUTPUT

```
                                                        *** MAIN SUPPLY DATA ***
         * PERIOD EFFECT * CUMULA EFFECT * END PERIOD * PERIOD DEM * ON HAND * ON HAND * REPAIR PETN * AVG AGE OF * SURVY * SURVY *
  PERIOD * REQN ** UNITS * REQN ** UNITS * BACKORDERS * IN UNITS  *   NEW   * REPAIR  *   PERIOD    * BACKORDERS *  DEM  *  REP  *
     1      50.00     68.75 75.612  76.260      5.000       16.000        0.       8.00        8.000          14.32       0.       1.0
     2      0.        0.    75.549  76.188     19.000       14.000        0.      10.00        2.000          14.30       0.       0.
     3      0.        0.    75.499  76.167     23.000        4.000        0.      19.00        9.000          14.30       0.       0.
     4      0.        0.    75.461  76.152     27.000        3.000        0.      15.00       15.000          14.29       0.       1.0
     5      0.        0.    75.411  76.033     25.000       23.000        0.      22.00        7.000          14.27       0.       0.
     6      0.        0.    75.361  76.013     29.000        4.000        0.      27.00        5.000          14.27       0.       0.
     7      33.33     33.33 75.340  76.004      0.           3.000       21.00    16.00       16.000          14.27       0.       0.
     8     100.00    100.00 75.356  76.024      0.          12.000        9.00    24.00        8.000          14.27       1.00     0.
     9      40.00     69.23 75.327  76.018      4.000       13.000        0.      23.00        5.000          14.26       0.       0.
    10      0.        0.    75.290  76.002      7.000        3.000        0.       7.00        7.000          14.25       0.       2.0
    11      0.        0.    75.227  75.885     30.000       23.000        0.      11.00        4.000          14.24       0.       0.
    12      0.        0.    75.190  75.870     33.000        3.000        0.      20.00        9.000          14.27       0.       1.0
    13      25.00      7.14 75.157  75.805      0.          14.000        4.00    21.00       21.000          14.27       1.00     3.0
    14      66.67     38.46 75.149  75.773      0.          13.000       10.00    30.00        9.000          14.27       0.       0.
    15     100.00    100.00 75.165  75.779      0.           4.000       32.00    40.00       10.000          14.27       1.00     0.
    16     100.00    100.00 75.177  75.799      0.          12.000       20.00     7.00        7.000          14.27       1.00     2.0
    17     100.00    100.00 75.198  75.823      0.          15.000        3.00    14.00        7.000          14.27       1.00     0.
    18     100.00    100.00 75.214  75.829      0.           4.000        1.00    25.00       11.000          14.27       0.       0.
    19     100.00    100.00 75.230  75.849      0.          12.000       15.00     8.00        8.000          14.27       1.00     0.
    20     100.00    100.00 75.247  75.855      0.           4.000       12.00    17.00        9.000          14.27       0.       0.
    21     100.00    100.00 75.259  75.860      0.           3.000        9.00    27.00       10.000          14.27       1.00     3.0
    22      28.57     32.14 75.205  75.778     19.000       20.000        0.      32.00        5.000          14.24       1.00     0.
    23      0.        0.    75.148  75.763     29.000        3.000        0.      39.00        7.000          14.23       0.       0.
    24      66.67     66.67 75.164  75.761      0.           3.000       18.00    52.00       13.000          14.23       1.00     0.
    25     100.00    100.00 75.180  75.784      0.          14.000        4.00     8.00        8.000          14.23       0.       0.
    26      66.67     30.77 75.172  75.745      9.000       13.000        0.      18.00       10.000          14.22       0.       2.0
    27      0.        0.    75.123  75.725     17.000        4.000        0.      23.00        5.000          14.21       0.       3.0
    28      20.00     23.08 75.078  75.679      7.000       13.000        0.      14.00       14.000          14.20       0.       0.
    29      25.00     25.00 75.045  75.666      0.           4.000        6.00    24.00       10.000          14.20       1.00     0.
    30      80.00     69.23 75.049  75.660      0.          13.000       19.00    32.00        8.000          14.20       1.00     0.
    31     100.00    100.00 75.065  75.667      0.           4.000       15.00     8.00        8.000          14.20       0.       3.0
    32     100.00    100.00 75.081  75.676      0.          12.000        5.00    18.00       10.000          14.20       0.       0.
    33     100.00    100.00 75.106  75.709      0.          14.000       51.00    29.00       11.000          14.20       0.       0.
    34     100.00    100.00 75.126  75.733      0.          15.000       36.00    14.00       14.000          14.20       0.       0.
    35     100.00    100.00 75.142  75.754      0.          13.000       23.00    23.00        9.000          14.20       0.       0.
    36     100.00    100.00 75.158  75.775      0.          13.000       11.00    31.00        8.000          14.20       1.00     0.
    37     100.00    100.00 75.171  75.779      0.           3.000        7.00     5.00        5.000          14.20       1.00     4.0
    38      75.00     58.33 75.170  75.766      5.000       12.000        0.      14.00        9.000          14.19       0.       4.0
    39      0.        0.    75.109  75.696     19.000       14.000        0.      20.00        6.000          14.17       0.       0.
    40      33.33     33.33 75.089  75.687      0.           3.000       47.00    14.00       14.000          14.17       0.       0.
    41     100.00    100.00 75.105  75.710      0.          14.000       33.00    23.00        9.000          14.17       0.       0.
    42     100.00    100.00 75.125  75.718      0.           5.000       28.00    32.00        9.000          14.17       1.00     0.
    43     100.00    100.00 75.142  75.742      0.          15.000       34.00    11.00       11.000          14.17       0.       0.
    44     100.00    100.00 75.154  75.746      0.           3.000       31.00    19.00        8.000          14.17       0.       4.0
    45     100.00    100.00 75.170  75.767      0.          13.000       18.00    27.00        3.000          14.17       0.       3.0
    46     100.00    100.00 75.190  75.793      0.          15.000        2.00     6.00        6.000          14.17       1.00     0.
    47      75.00     75.00 75.190  75.792      0.           4.000       23.00    14.00        3.000          14.17       1.00     4.0
    48     100.00    100.00 75.202  75.797      0.           3.000       49.00    23.00        9.000          14.17       0.       0.
    49     100.00    100.00 75.222  75.821      0.          15.000       51.00     8.00        8.000          14.17       1.00     0.
    50     100.00    100.00 75.230  75.824      0.           2.000       49.00    12.00        4.000          14.17       0.       0.
    51     100.00    100.00 75.245  75.842      0.          11.000       38.00    20.00        8.000          14.17       0.       0.
    52     100.00    100.00 75.257  75.846      0.           3.000       35.00    11.00       11.000          14.17       0.       3.0
    53     100.00    100.00 75.273  75.878      0.          20.000       15.00    20.00        9.000          14.17       0.       0.
    54     100.00    100.00 75.289  75.884      0.           4.000       39.00    31.00       11.000          14.17       0.       0.
    55     100.00    100.00 75.313  75.925      0.          26.000       13.00     7.00        7.000          14.17       1.00     0.
    56     100.00    100.00 75.321  75.928      0.           2.000       11.00    17.00       10.000          14.17       0.       0.
    57     100.00    100.00 75.329  75.931      0.           2.000        9.00    24.00        7.000          14.17       1.00     0.
```

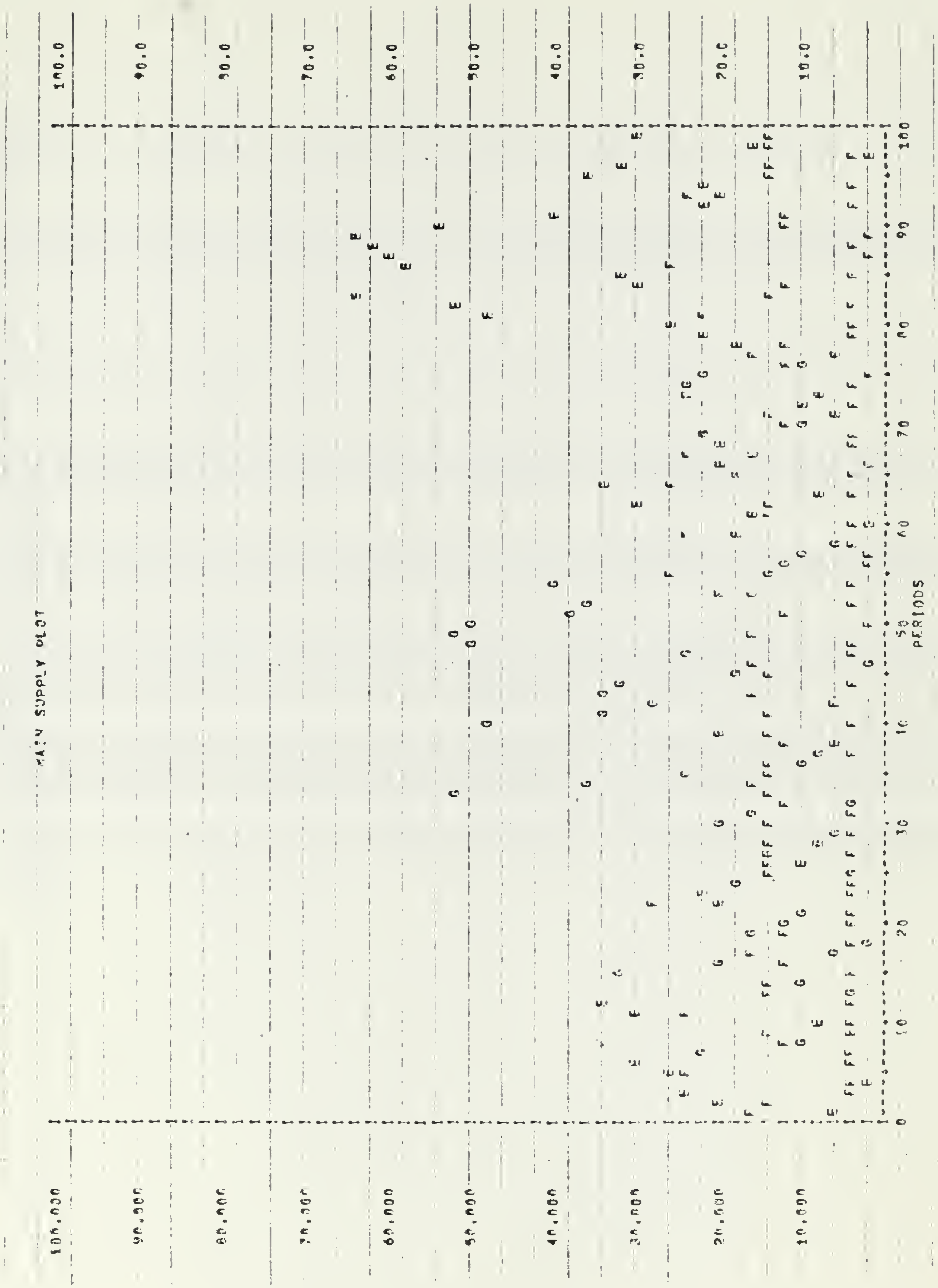
MAIN SUPPLY PLOT LEGEND

Program Location	Definition of Item to be Plotted	Plot Symbol	Input for Scales	
			Minimum	Maximum
Y (I,1)	Period Requisition Effectiveness	A	TEMPB (1) 0.0	TEMPT (1) 0.0
Y (I,2)	Period Unit Effectiveness	B	TEMPB (2) 0.0	TEMPT (2) 0.0
Y (I,3)	Cumulative Requisition Effectiveness	C	TEMPB (3) 0.0	TEMPT (3) 0.0
Y (I,4)	Cumulative Unit Effectiveness	D	TEMPB (4) 0.0	TEMPT (4) 0.0
Y (I,5)	End of Period Backorders	E	TEMPB (5) 0.0	TEMPT (5) 100.0
Y (I,6)	Period Demand Units	F	TEMPB (6) 0.0	TEMPT (6) 100.0
Y (I,7)	On Hand Ready of Issue	G	TEMPB (7) 0.0	TEMPT (7) 100.0
Y (I,8)	On Hand Awaiting Repair Induction	H	TEMPB (8) 0.0	TEMPT (8) 0.0

Note: 1. Left scale of Plot will use minimum and maximum input values of any of the above if input parameter (N1) is set equal to array location (In this example N1 = 5)

2. Right scale of Plot will use minimum and maximum input values of any of the above if input parameter (N2) is set equal to array location (In this example N2 = 5)

TABLE V


MAIN SUPPLY PLOT
PERIODS
0
10
20
30
40
50
60
70
80
90
100
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0

```
                                                              *** SUB SUPPLY WEST ***
         *   EFFECTIVENESS    * PERIOD *   ISSUES * END PERIOD * ON HAND * SURVEYS *
  PERIOD * PERIOD  * CUMULA * DEMAND * ON TIME * BACKORDERS *    NEW    * DEMAND   *
      1    100.000   97.693     3.00      3.00         0.        10.00      1.00
      2    100.000   97.694     3.00      3.00         0.         7.00      1.00
      3    100.000   97.696     4.00      4.00         0.        12.00      0.
      4    100.000   97.697     2.00      2.00         0.        10.00      0.
      5    100.000   97.699     4.00      4.00         0.         6.00      0.
      6    100.000   97.700     2.00      2.00         0.         4.00      0.
      7    100.000   97.702     4.00      4.00         0.         0.        0.
      8     66.667   97.683     3.00      2.00         0.         7.00      0.
      9    100.000   97.684     3.00      3.00         0.         4.00      0.
     10    100.000   97.685     2.00      2.00         0.        12.00      1.00
     11    100.000   97.687     3.00      3.00         0.         9.00      0.
     12    100.000   97.688     4.00      4.00         0.        14.00      1.00
     13    100.000   97.690     4.00      4.00         0.        10.00      0.
     14    100.000   97.692     3.00      3.00         0.         7.00      0.
     15    100.000   97.694     4.00      4.00         0.         3.00      0.
     16    100.000   97.695     3.00      3.00         0.        12.00      0.
     17    100.000   97.696     3.00      3.00         0.        16.00      0.
     18    100.000   97.698     3.00      3.00         0.        23.00      0.
     19    100.000   97.700     4.00      4.00         0.        19.00      0.
     20    100.000   97.702     5.00      5.00         0.        14.00      1.00
     21    100.000   97.703     3.00      3.00         0.        11.00      0.
     22    100.000   97.705     4.00      4.00         0.        16.00      0.
     23    100.000   97.706     3.00      3.00         0.        13.00      0.
     24    100.000   97.708     3.00      3.00         0.        18.00      1.00
     25    100.000   97.709     3.00      3.00         0.        15.00      0.
     26    100.000   97.711     4.00      4.00         0.        11.00      0.
     27    100.000   97.712     2.00      2.00         0.        14.00      0.
     28    100.000   97.713     3.00      3.00         0.        11.00      0.
     29    100.000   97.715     3.00      3.00         0.        19.00      0.
     30    100.000   97.716     2.00      2.00         0.        17.00      0.
     31    100.000   97.717     4.00      4.00         0.        13.00      1.00
     32    100.000   97.719     3.00      3.00         0.        16.00      0.
     33    100.000   97.721     4.00      4.00         0.        12.00      0.
     34    100.000   97.722     4.00      4.00         0.         8.00      0.
     35    100.000   97.723     2.00      2.00         0.        10.00      0.
     36    100.000   97.725     4.00      4.00         0.        15.00      1.00
     37    100.000   97.726     3.00      3.00         0.        12.00      1.00
     38    100.000   97.728     4.00      4.00         0.        18.00      0.
     39    100.000   97.730     4.00      4.00         0.        14.00      0.
     40    100.000   97.731     3.00      3.00         0.        11.00      1.00
     41    100.000   97.733     3.00      3.00         0.        13.00      0.
     42    100.000   97.734     3.00      3.00         0.        10.00      1.00
     43    100.000   97.736     4.00      4.00         0.        11.00      0.
     44    100.000   97.737     2.00      2.00         0.        20.00      1.00
     45    100.000   97.738     3.00      3.00         0.        17.00      0.
     46    100.000   97.739     2.00      2.00         0.        15.00      0.
     47    100.000   97.740     2.00      2.00         0.        13.00      0.
     48    100.000   97.741     2.00      2.00         0.        21.00      0.
     49    100.000   97.742     3.00      3.00         0.        18.00      1.00
     50    100.000   97.743     3.00      3.00         0.        15.00      1.00
     51    100.000   97.745     3.00      3.00         0.        12.00      0.
     52    100.000   97.746     3.00      3.00         0.         9.00      0.
     53    100.000   97.748     4.00      4.00         0.         5.00      0.
     54    100.000   97.750     4.00      4.00         0.         9.00      0.
     55    100.000   97.751     3.00      3.00         0.        15.00      0.
     56    100.000   97.752     3.00      3.00         0.        12.00      0.
     57    100.000   97.753     3.00      3.00         0.         9.00      0.
```

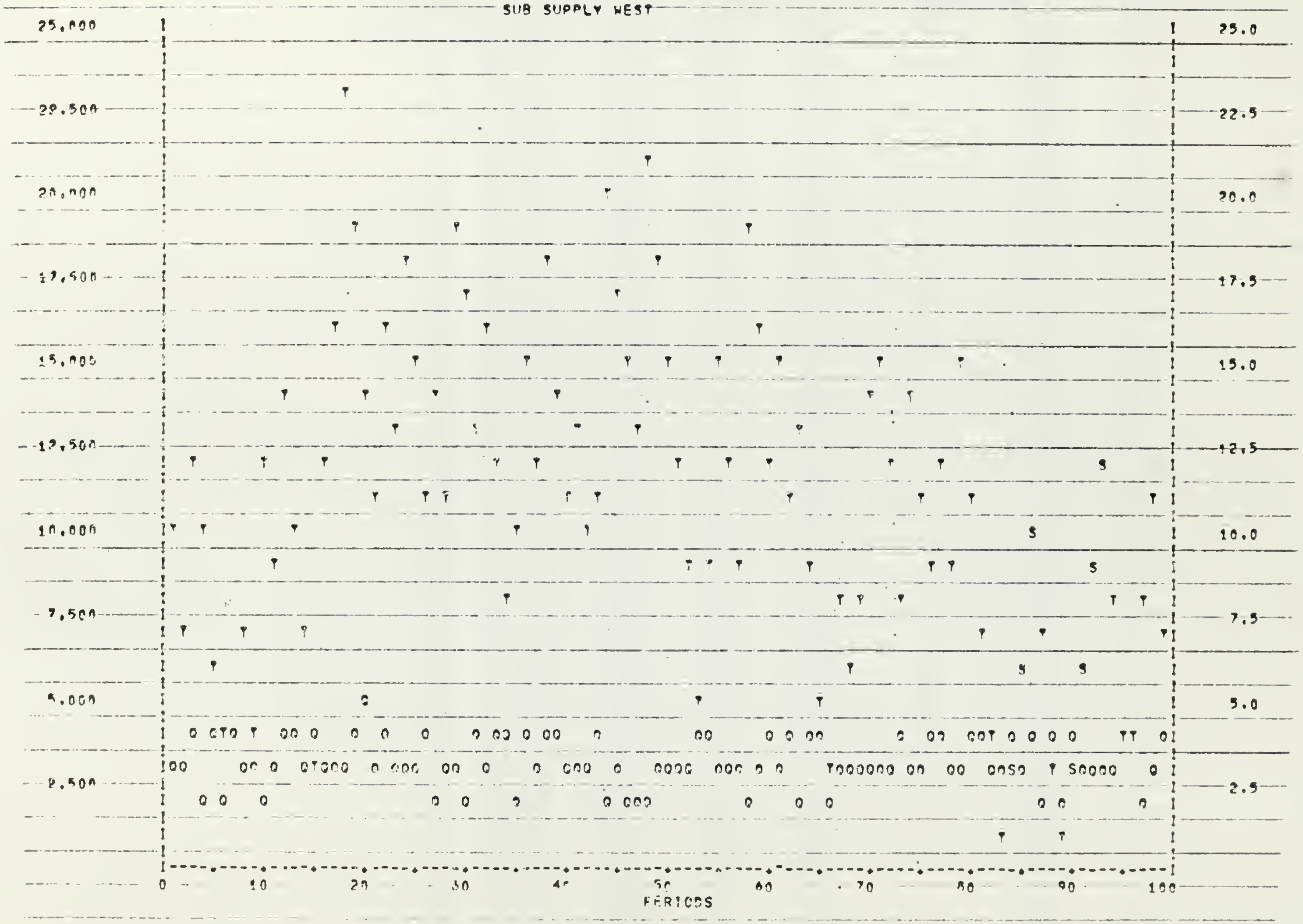
SUBSUPPLY WEST PLOT LEGEND

Program Location	Definition of Item to be Plotted	Plot Symbol	Input for Scales	
			Minimum	Maximum
Y (I, 9)	Period Effectiveness	O	TEMPB (9) 0.0	TEMPT (9) 0.0
Y (I,10)	Cumulative Effectiveness	P	TEMPB (10) 0.0	TEMPT (10) 0.0
Y (I,11)	Period Demand	Q	TEMPB (11) 0.0	TEMPT (11) 25.0
Y (I,12)	Issues on Time	R	TEMPB (12) 0.0	TEMPT (12) 0.0
Y (I,13)	End of Period Backorders	S	TEMPB (13) 0.0	TEMPT (13) 25.0
Y (I,14)	End of Period on Hand Ready for Issue	T	TEMPB (14) 0.0	TEMPT (14) 25.0

Note: 1. Left scale of Plot will use minimum and maximum input values of any of the above if input parameter (N3) is set equal to array location (In this example N3 = 11)

2. Right scale of Plot will use minimum and maximum input values of any of the above if input parameter (N4) is set equal to array location (In this example N4 = 13)

TABLE VI


SUB SUPPLY WEST
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
10
20
30
40
50
60
70
80
90
100
PERIODS

```
---------------------------------------------------------------------*** SUB SUPPLY EAST ***-----
        *   EFFECTIVENESS   * PERIOD *  ISSUES * END PERIOD * ON HAND * SURVEYS *
---PERIOD-*-PERIOD-*-CUMULA-*-DEMAND-*-ON TIME-*-BACKORDERS-*---NEW---*-DEMAND--*---
      1    100.000    99.330     5.00      5.00        0.        20.00     2.00
      2    100.000    99.331     2.00      2.00        0.        16.00     0.
      3    100.000    99.331     4.00      4.00        0.        23.00     1.00
      4    100.000    99.332     4.00      4.00        0.        19.00     0.
      5    100.000    99.332     2.00      2.00        0.        17.00     0.
      6    100.000    99.333     3.00      3.00        0.        17.00     1.00
      7    100.000    99.333     4.00      4.00        0.        13.00     1.00
      8    100.000    99.333     3.00      3.00        0.        10.00     1.00
      9    100.000    99.334     3.00      3.00        0.        18.00     1.00
     10    100.000    99.334     4.00      4.00        0.        14.00     0.
     11    100.000    99.335     4.00      4.00        0.        18.00     1.00
     12    100.000    99.336     5.00      5.00        0.        13.00     0.
     13    100.000    99.336     3.00      3.00        0.        10.00     0.
     14    100.000    99.336     3.00      3.00        0.         7.00     0.
     15    100.000    99.337     4.00      4.00        0.         5.00     0.
     16    100.000    99.337     2.00      2.00        0.        21.00     1.00
     17    100.000    99.338     3.00      3.00        0.        21.00     0.
     18    100.000    99.338     3.00      3.00        0.        18.00     1.00
     19    100.000    99.338     2.00      2.00        0.        27.00     0.
     20    100.000    99.339     3.00      3.00        0.        24.00     1.00
     21    100.000    99.339     5.00      5.00        0.        19.00     0.
     22    100.000    99.340     2.00      2.00        0.        17.00     0.
     23    100.000    99.340     3.00      3.00        0.        14.00     0.
     24    100.000    99.340     3.00      3.00        0.        11.00     0.
     25    100.000    99.341     2.00      2.00        0.         9.00     0.
     26    100.000    99.341     4.00      4.00        0.        16.00     0.
     27    100.000    99.342     4.00      4.00        0.        12.00     1.00
     28    100.000    99.342     4.00      4.00        0.         8.00     0.
     29    100.000    99.342     2.00      2.00        0.         7.00     0.
     30    100.000    99.343     3.00      3.00        0.         4.00     0.
     31    100.000    99.343     4.00      4.00        0.        11.00     1.00
     32    100.000    99.344     3.00      3.00        0.        15.00     0.
     33    100.000    99.344     4.00      4.00        0.        11.00     0.
     34    100.000    99.345     4.00      4.00        0.        16.00     0.
     35    100.000    99.345     4.00      4.00        0.        12.00     0.
     36    100.000    99.346     3.00      3.00        0.        20.00     1.00
     37    100.000    99.346     3.00      3.00        0.        17.00     0.
     38    100.000    99.347     3.00      3.00        0.        14.00     0.
     39    100.000    99.347     3.00      3.00        0.        11.00     0.
     40    100.000    99.347     4.00      4.00        0.        17.00     0.
     41    100.000    99.348     3.00      3.00        0.        14.00     0.
     42    100.000    99.348     4.00      4.00        0.        20.00     1.00
     43    100.000    99.349     4.00      4.00        0.        16.00     1.00
     44    100.000    99.349     4.00      4.00        0.        12.00     1.00
     45    100.000    99.350     3.00      3.00        0.         9.00     1.00
     46    100.000    99.350     3.00      3.00        0.         6.00     1.00
     47    100.000    99.351     3.00      3.00        0.        15.00     0.
     48    100.000    99.351     4.00      4.00        0.        23.00     0.
     49    100.000    99.352     4.00      4.00        0.        19.00     1.00
     50    100.000    99.352     2.00      2.00        0.        17.00     1.00
     51    100.000    99.352     2.00      2.00        0.        15.00     0.
     52    100.000    99.353     4.00      4.00        0.        22.00     0.
     53    100.000    99.353     4.00      4.00        0.        18.00     0.
     54    100.000    99.354     4.00      4.00        0.        14.00     0.
     55    100.000    99.354     2.00      2.00        0.        12.00     1.00
     56    100.000    99.354     4.00      4.00        0.        17.00     0.
     57    100.000    99.355     3.00      3.00        0.        14.00     0.
-------------------------------------------------------------------------------------
```

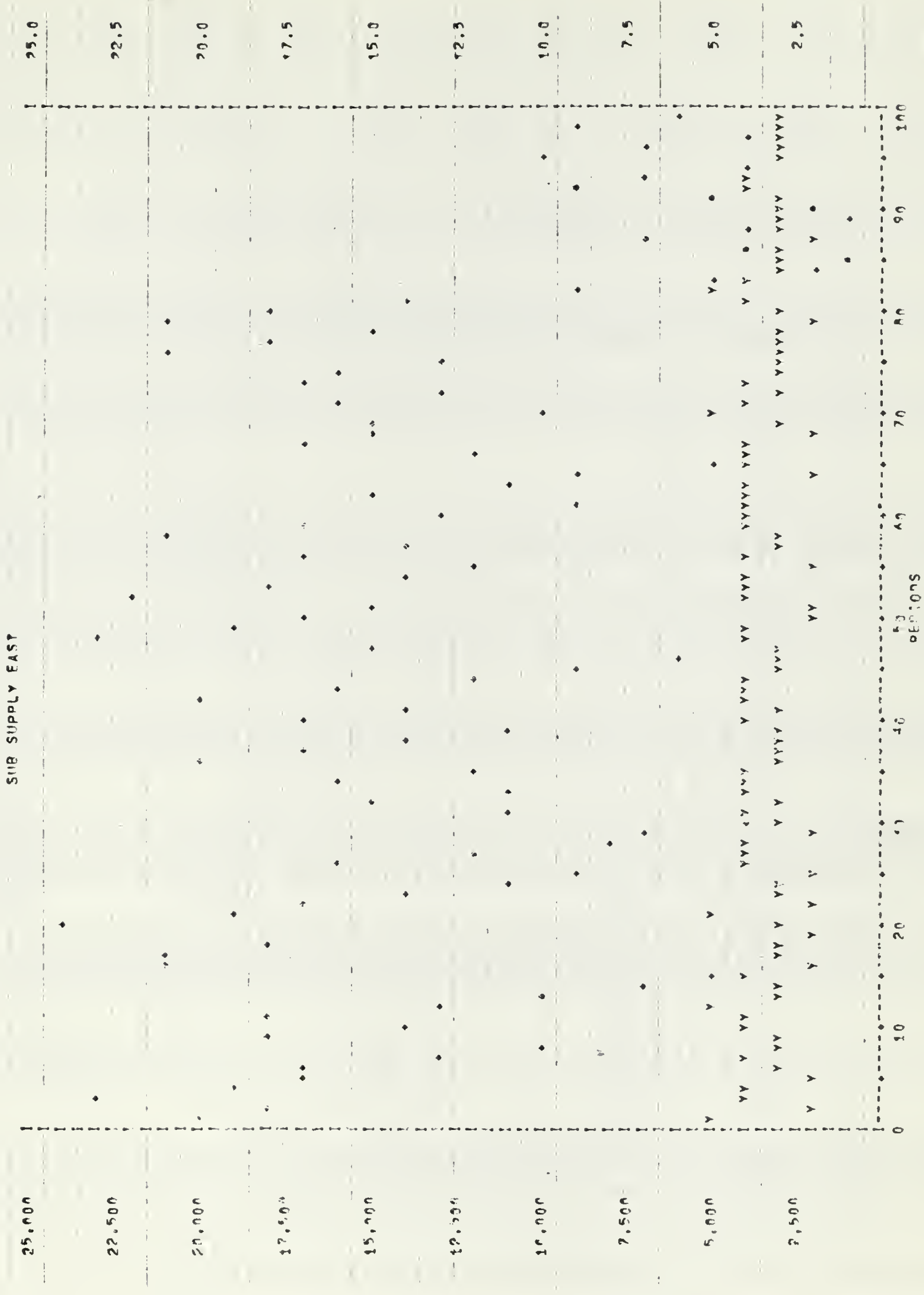
SUBSUPPLY EAST PLOT LEGEND

Program Location	Definition of Item to be Plotted	Plot Symbol	Input for Scales	
			Minimum	Maximum
Y (I, 15)	Period Effectiveness	U	TEMPB (15) 0.0	TEMPT (15) 0.0
Y (I, 16)	Cumulative Effectiveness	X	TEMPB (16) 0.0	TEMPT (16) 0.0
Y (I, 17)	Period Demand	Y	TEMPB (17) 0.0	TEMPT (17) 25.0
Y (I, 18)	Issues on Time	Z	TEMPB (18) 0.0	TEMPT (18) 0.0
Y (I, 19)	End of Period Backorders	*	TEMPB (19) 0.0	TEMPT (19) 25.0
Y (I, 20)	End of Period on Hand Ready for Issue	+	TEMPB (20) 0.0	TEMPT (20) 25.0

Note: 1. Left scale of Plot will use minimum and maximum input values of any of the above if input parameter (N5) is set equal to array location (In this example N5 = 17)

2. Right scale of Plot will use minimum and maximum input values of any of the above if input parameter (N6) is set equal to array location (In this example N6 = 19)

TABLE VII


SUB SUPPLY EAST
PERIODS
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
10
20
30
40
50
60
70
80
90
100

```
                                           ***  REORDER POINT PRESENTATION  ***
       * PROCURMT * BACKORDER * PLT *    * PROCURMT * REPAIR    * RLT *   *  REPAIR   *    DUE    *   DUE    * ON HAND *  REC   *  REC    *
PERIOD * SAFE LEV * FILE MAIN * DEMFOR  * REORD PT * SAFE LEV * DEMFOR * REORD PT  * CONTRACT * REPAIR   *  MAIN   *REPAIR*CONTRACT *
   1       30.01        5.00    360.08    395.09      30.01     180.04    215.05       93.00    159.00      0.         0.       0.
   2       30.01       19.00    360.08    409.09      30.01     180.04    229.05       93.00    159.00      0.         0.       0.
   3       30.81       23.00    369.67    423.47      30.81     184.83    238.64       93.00    159.00      0.         0.       0.
   4       30.81        2.00    369.67    402.47      30.81     184.83    217.64      114.00    153.00      0.        24.0      0.
   5       30.81       25.00    369.67    425.47      30.81     184.83    240.64      114.00    153.00      0.         0.       0.
   6       30.64       29.00    367.73    427.38      30.64     183.87    243.51      114.00    153.00      0.         0.       0.
   7       30.64        0.      367.73    398.38      30.64     183.87    214.51       88.00    153.00     21.00      27.0     26.00
   8       30.64        0.      367.73    398.38      30.64     183.87    214.51       88.00    153.00      9.00       0.       0.
   9       30.12        4.00    361.39    395.50      30.12     180.69    214.81       88.00    153.00      0.         0.       0.
  10       30.12        7.00    361.39    398.50      30.12     180.69    217.81       88.00    180.00      0.         0.       0.
  11       30.12       30.00    361.39    421.50      30.12     180.69    240.81       88.00    180.00      0.         0.       0.
  12       29.89       33.00    358.71    421.60      29.89     179.35    242.25       88.00    179.00      0.         0.       0.
  13       29.89        0.      358.71    388.60      29.89     179.35    209.25       64.00    169.00      4.00      27.0     24.00
  14       29.89        0.      358.71    388.60      29.89     179.35    209.25       64.00    150.00     10.00      19.0      0.
  15       30.11        0.      361.37    391.48      30.11     180.68    210.80       64.00    124.00     32.00      26.0      0.
  16       30.11        0.      361.37    391.48      30.11     180.68    210.80       64.00    162.00     23.00       0.       0.
  17       30.11        0.      361.37    391.48      30.11     180.68    210.80       64.00    162.00      5.00       0.       0.
  18       30.29        0.      363.49    393.78      30.29     181.75    212.04       64.00    162.00      1.00       0.       0.
  19       30.29        0.      363.49    393.78      30.29     181.75    212.04       64.00    162.00     16.00      27.0      0.
  20       30.29        0.      363.49    393.78      30.29     181.75    212.04       64.00    163.00     12.00       0.       0.
  21       28.03        0.      336.40    364.43      28.03     168.20    196.23       64.00    157.00      9.00       0.       0.
  22       28.03       19.00    336.40    383.43      28.03     168.20    215.23       64.00    157.00      0.         0.       0.
  23       28.03       22.00    336.40    386.43      28.03     168.20    218.23       64.00    157.00      0.         0.       0.
  24       29.23        0.      350.72    379.94      29.23     175.36    204.58       64.00    114.00     18.00      43.0      0.
  25       29.23        0.      350.72    379.94      29.23     175.36    204.58       64.00    166.00      4.00       0.       0.
  26       29.23        9.00    350.72    388.94      29.23     175.36    213.58       64.00    164.00      0.         0.       0.
  27       29.58       13.00    354.97    397.55      29.58     177.49    220.07       64.00    161.00      0.         0.       0.
  28       29.58        8.00    354.97    392.55      29.58     177.49    215.07       70.00    184.00      0.         0.      18.00
  29       29.58        0.      354.97    384.55      29.58     177.49    207.07       70.00    166.00      6.00      18.0      0.
  30       29.66        0.      355.98    385.64      29.66     177.99    207.65       70.00    140.00     19.00      26.0      0.
  31       29.66        0.      355.98    385.64      29.66     177.99    207.65       70.00    169.00     15.00       0.       0.
  32       29.66        0.      355.98    385.64      29.66     177.99    207.65       70.00    169.00      3.00       0.       0.
  33       29.73        0.      356.78    386.51      29.73     178.39    208.12       45.00    132.00     51.00      37.0     25.00
  34       29.73        0.      356.78    386.51      29.73     178.39    208.12       45.00    161.00     36.00       0.       0.
  35       29.73        0.      356.78    386.51      29.73     178.39    208.12       45.00    161.00     23.00       0.       0.
  36       31.99        0.      383.83    415.81      31.99     191.91    223.90       45.00    161.00     10.00       0.       0.
  37       31.99        0.      383.83    415.81      31.99     191.91    223.90       79.00    188.00      7.00       0.       0.
  38       31.99        5.00    383.83    420.81      31.99     191.91    228.90       79.00    184.00      0.         0.       0.
  39       31.39       19.00    376.66    427.05      31.39     188.33    238.72       79.00    184.00      0.         0.       0.
  40       31.39        0.      376.66    408.05      31.39     188.33    219.72       79.00    135.00     47.00      69.0      0.
  41       31.39        0.      376.66    408.05      31.39     188.33    219.72       79.00    135.00     33.00       0.       0.
  42       29.51        0.      354.13    383.64      29.51     177.06    206.58       79.00    135.00     28.00       0.       0.
  43       29.51        0.      354.13    383.64      29.51     177.06    206.58       58.00    167.00     34.00       0.      21.00
  44       29.51        0.      354.13    383.64      29.51     177.06    206.58       58.00    163.00     31.00       0.       0.
  45       29.81        0.      357.70    387.51      29.81     178.85    208.66       58.00    160.00     18.00       0.       0.
  46       29.81        0.      357.70    387.51      29.81     178.85    208.66       58.00    187.00      2.00       0.       0.
  47       29.81        0.      357.70    387.51      29.81     178.85    208.66       58.00    156.00     23.00      25.0      0.
  48       28.45        0.      341.36    369.81      28.45     170.68    199.13       58.00    127.00     49.00      29.0      0.
  49       28.45        0.      341.36    369.81      28.45     170.68    199.13       58.00    133.00     51.00      17.0      0.
  50       28.45        0.      341.36    369.81      28.45     170.68    199.13       58.00    133.00     49.00       0.       0.
  51       28.36        0.      340.29    368.65      28.36     170.14    198.50       58.00    133.00     38.00       0.       0.
  52       28.36        0.      340.29    368.65      28.36     170.14    198.50       58.00    150.00     35.00       0.       0.
  53       28.36        0.      340.29    368.65      28.36     170.14    198.50       58.00    150.00     15.00       0.       0.
  54       28.09        0.      337.03    365.12      28.09     168.52    196.60       58.00    122.00     39.00      28.0      0.
  55       28.09        0.      337.03    365.12      28.09     168.52    196.60       59.00    153.00     13.00       0.       0.
  56       28.09        0.      337.03    365.12      28.09     168.52    196.60       58.00    153.00     11.00       0.       0.
  57       28.47        0.      341.63    370.09      28.47     170.81    199.28       58.00    153.00      9.00       0.       0.
```

REORDER POINT PLOT LEGEND

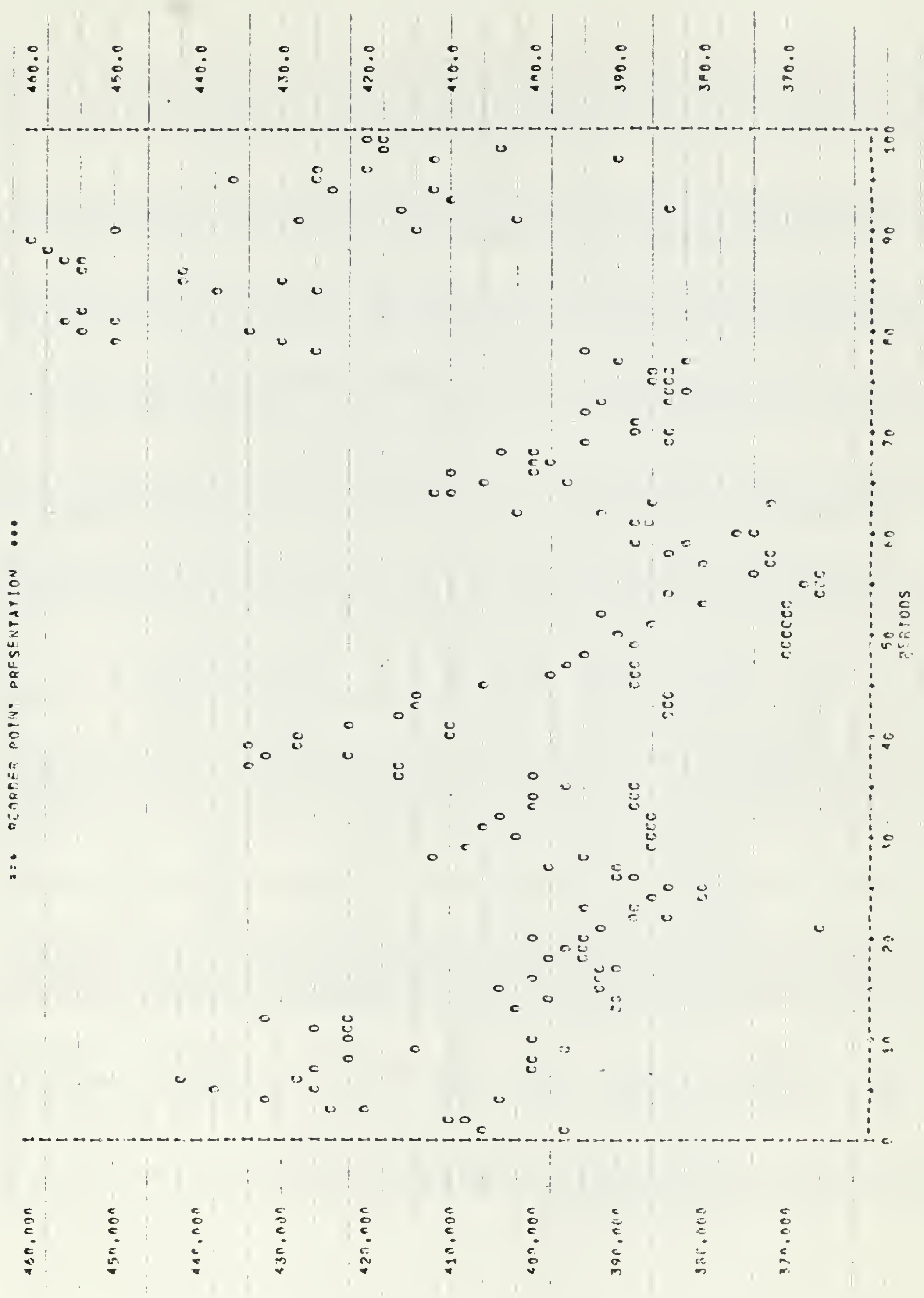
Program Location	Definition of Item to be Plotted	Plot Symbol	Input for Scales	
			Minimum	Maximum
X(J1,1)	Procurement Safety Level (PSL)	A	TSCAB(1) 0.0	TSCAT(1) 0.0
X(J1,2)	Total Backorder File Main (TOBOFM)	B	TSCAB(2) 0.0	TSCAT(2) 0.0
X(J1,3)	PRP (PSL + TOBOFM + (PLT x DEMFOR))	C	TSCAB(3) 360.0	TSCAT(3) 460.0
X(J1,4)	Repair Safety Level	D	TSCAB(4) 0.0	TSCAT(4) 0.0
X(J1,5)	RRP (RSL + TOBOFM + (RLT x DEMFOR))	E	TSCAB(5) 0.0	TSCAT(5) 0.0
X(J1,6)	OHM	F	TSCAB(6) 0.0	TSCAT(6) 0.0
X(J1,7)	DUFC	G	TSCAB(7) 0.0	TSCAT(7) 0.0
X(J1,8)	DUFR	H	TSCAB(8) 0.0	TSCAT(8) 0.0
X(J1,9)	HARDA + (OHMR x AA) + (AA x BB) x DEMFOR (PLT - RLT)	O	TSCAB(9) 360.0	TSCAT(9) 460.0

Note:

1. Left scale of Plot will use minimum and maximum input values of any of the above if input parameter (N7) is set equal to array location (In this example N7 = 3)

2. Right scale of Plot will use minimum and maximum input values of any of the above if input parameter (N8) is set equal to array location (In this example N8 = 9)

TABLE VIII


*** RECORDER POINT PRESENTATION ***
460.000
450.000
440.000
430.000
420.000
410.000
400.000
390.000
380.000
370.000
460.0
450.0
440.0
430.0
420.0
410.0
400.0
390.0
380.0
370.0
0
10
20
30
40
50
60
70
80
90
100
PERIODS

```
                                                     ***   COST   DATA   ***
         *    REPAIR COST     *   NEW UNIT COST    * TRANS COST NEW     * TRANS COST REPAIR.     TOTAL COST     * INVESTMENT  *
 PERIOD  * PERIOD  * AVERAGE  * PERIOD  * AVERAGE  * PERIOD  * AVERAGE  * PERIOD  * AVERAGE  * PERIOD  * AVERAGE  *   LEVEL     *
    1     2400.00    803.73       0.      354.63       0.      112.69    432.00    741.77   2832.00    2012.83     60448.98
    2        0.      803.20       0.      354.40       0.      112.62    144.00    741.37    144.00    2011.59     60449.58
    3        0.      802.66       0.      354.16     205.20    112.68   1218.75    741.69   1423.95    2011.19     60451.15
    4     2700.00    803.93       0.      353.93       0.      112.60    684.00    741.65   3384.00    2012.11     60452.79
    5        0.      803.39       0.      353.69       0.      112.53    531.00    741.51    531.00    2011.12     60454.42
    6        0.      802.86       0.      353.46     180.00    112.57    743.25    741.52    923.25    2010.40     60455.86
    7        0.      802.32    5225.00    356.69       0.      112.50    893.25    741.62   6118.25    2013.13     60457.30
    8        0.      801.79       0.      356.45     228.00    112.57    486.00    741.45    714.00    2012.27     60458.73
    9        0.      801.26       0.      356.22     162.00    112.51    794.25    741.48    956.25    2011.57     60459.52
   10     2700.00    802.52       0.      355.98     228.00    112.68    423.00    741.27   3351.00    2012.45     60460.24
   11        0.      801.99       0.      355.75     162.00    112.72    288.00    740.97    450.00    2011.42     60460.97
   12     1900.00    802.71       0.      355.51     205.20    112.78    621.00    740.89   2726.20    2011.89     60461.42
   13     2600.00    803.90    4825.00    358.47       0.      112.70   1626.00    741.48   9051.00    2016.55     60461.87
   14        0.      803.37       0.      358.23       0.      112.63    743.25    741.48    743.25    2015.71     60462.32
   15        0.      802.84       0.      357.99     180.00    112.67   1393.50    741.91   1573.50    2015.41     60463.03
   16     2700.00    804.09       0.      357.76     309.60    112.80    432.00    741.70   3441.60    2016.35     60463.75
   17        0.      803.56       0.      357.52     285.60    112.92    288.00    741.40    573.60    2015.40     60464.47
   18        0.      803.03       0       357.28     228.00    112.99   1281.00    741.76   1509.00    2015.07     60465.39
   19        0.      802.50       0.      357.05       0.      112.92    992.25    741.92    992.25    2014.40     60466.39
   20        0.      801.97       0.      356.81       0.      112.84    387.00    741.69    387.00    2013.32     60467.38
   21     4300.00    804.28       0.      356.58       0.      112.77   1044.75    741.89   5344.75    2015.52     60465.65
   22        0.      803.75       0.      356.34     205.20    112.83    387.00    741.66    592.20    2014.58     60463.53
   23        0.      803.22       0.      356.11       0.      112.76    477.00    741.48    477.00    2013.57     60461.42
   24        0.      802.69       0.      355.88     182.40    112.80   1193.25    741.78   1375.65    2013.15     60460.74
   25        0.      802.17       0.      355.64       0.      112.73    387.00    741.55    387.00    2012.08     60460.25
   26     1800.00    802.62       0.      355.41      90.00    112.74    477.00    741.37   2367.00    2012.32     60459.77
   27     2600.00    804.00       0.      355.18     114.00    112.71   1308.00    741.75   4022.00    2013.63     60459.71
   28        0.      803.47    3625.00    357.32       0.      112.64    477.00    741.57   4102.00    2015.00     60459.66
   29        0.      802.95       0.      357.08     250.80    112.73    769.50    741.59   1020.30    2014.35     60459.60
   30        0.      802.43       0.      356.85       0.      112.66   1356.75    741.99   1356.75    2013.92     60459.65
   31     3700.00    804.31       0.      356.62      72.00    112.63    288.00    741.69   4060.00    2015.25     60459.76
   32        0.      803.79       0.      356.38     244.80    112.72    531.00    741.55    775.80    2014.44     60459.87
   33        0.      803.25    5025.00    359.43       0.      112.64   1671.75    742.16   6696.75    2017.50     60460.05
   34        0.      802.74       0.      359.20      72.00    112.62    720.00    742.15    792.00    2016.70     60460.24
   35        0.      802.22       0.      358.96      91.20    112.60    432.00    741.94    523.20    2015.73     60460.43
   36        0.      801.69       0.      358.73     367.20    112.77    975.75    742.10   1342.95    2015.29     60463.30
   37     4800.00    804.30       0.      358.50       0.      112.70    189.00    741.74   4989.00    2017.22     60466.50
   38     2100.00    805.14       0.      358.26     228.00    112.77    531.00    741.60   2859.00    2017.77     60469.69
   39        0.      804.62       0.      358.03       0.      112.70   1067.25    741.81   1067.25    2017.15     60472.16
   40        0.      804.09       0.      357.80      90.00    112.68   1716.75    742.44   1806.75    2017.02     60474.50
   41        0.      803.57       0.      357.56     114.00    112.68    432.00    742.24    546.00    2016.06     60476.84
   42        0.      803.05       0.      357.33       0.      112.61    708.00    742.22    708.00    2015.21     60476.95
   43        0.      802.53    4225.00    359.84     204.00    112.67    576.00    742.11   5005.00    2017.15     60476.80
   44     2500.00    803.63       0.      359.61     250.80    112.76    333.00    741.85   3083.80    2017.84     60476.65
   45     2900.00    804.95       0.      359.37       0.      112.69    987.00    742.01   3887.00    2019.05     60476.86
   46        0.      804.43       0.      359.14       0.      112.61    189.00    741.65    189.00    2017.87     60477.42
   47     1700.00    805.05       0.      358.91     180.00    112.66    801.75    741.69   2681.75    2018.30     60477.39
   48        0.      804.52       0.      358.68     228.00    112.73   1428.00    742.13   1656.00    2018.07     60476.05
   49        0.      804.01       0.      358.45       0.      112.66    705.75    742.11    705.75    2017.22     60474.58
   50        0.      803.49       0.      358.21       0.      112.59    144.00    741.72    144.00    2016.01     60473.11
   51        0.      802.97       0.      357.98       0.      112.51    764.25    741.74    764.25    2015.20     60471.54
   52     2800.00    804.26       0.      357.75     144.00    112.53    576.00    741.63   3520.00    2016.17     60469.90
   53        0.      803.74       0.      357.52       0.      112.46    531.00    741.49    531.00    2015.21     60468.27
   54        0.      803.22       0.      357.29     182.40    112.51   1431.00    741.94   1613.40    2014.94     60466.32
   55        0.      802.70       0.      357.06     205.20    112.57    288.00    741.65    493.20    2013.98     60464.37
   56        0.      802.19       0.      356.83     215.00    112.63    630.00    741.57    845.00    2013.22     60462.43
   57        0.      801.67       0.      356.60       0.      112.56    959.25    741.71    959.25    2012.55     60460.94
```

COST DATA PLOT LEGEND

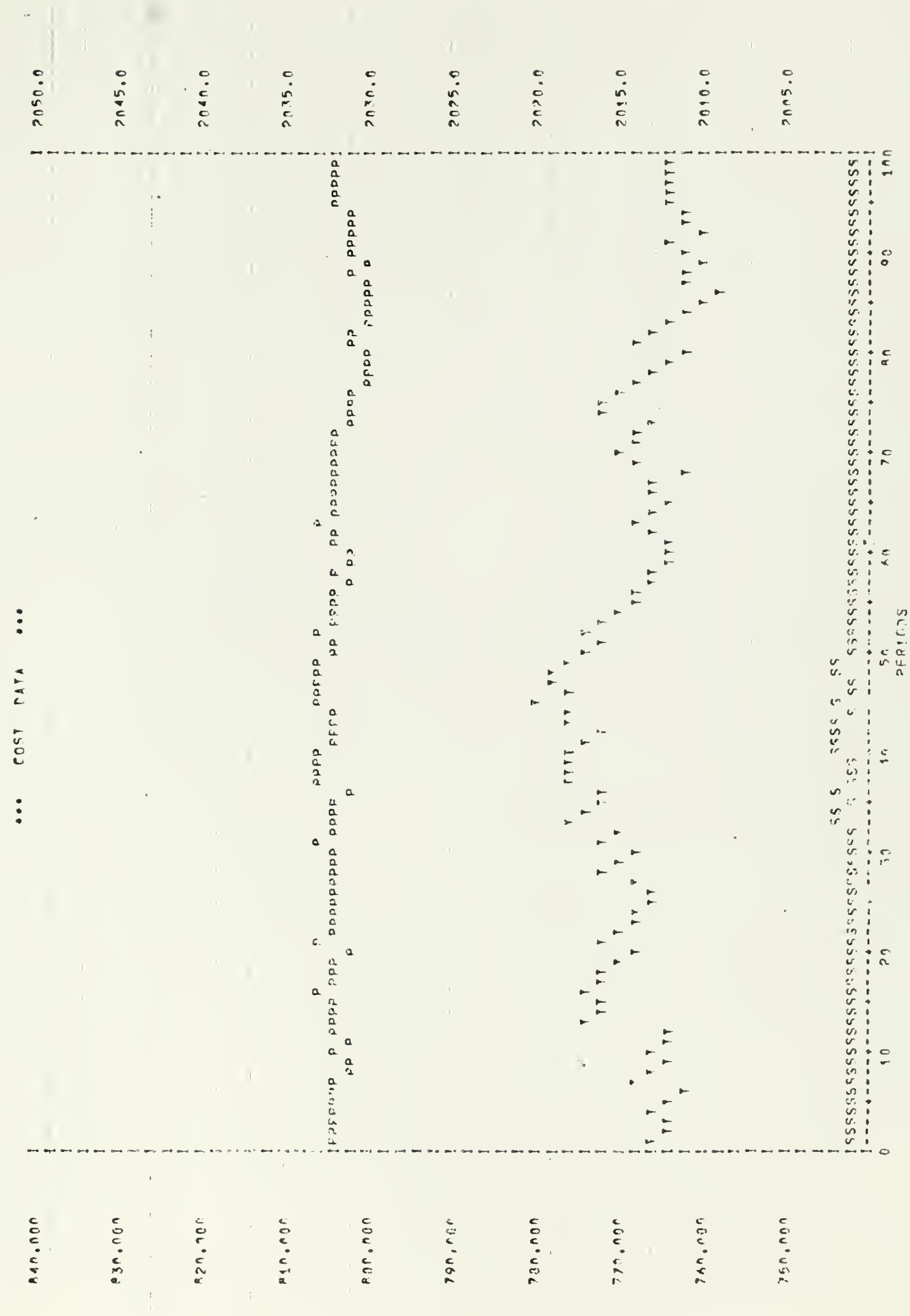
Program Location	Definition of Item to be Plotted	Plot Symbol	Input for Scales	
			Minimum	Maximum
X(J1,10)	Average Repair Cost	P	TSCAB(10) 0.0	TSCAT(10) 1000.0
X(J1,11)	Average New Units Cost	Q	TSCAB(11) 0.0	TSCAT(11) 0.0
X(J1,12)	Average Transportation New	R	TSCAB(12) 0.0	TSCAT(12) 0.0
X(J1,13)	Average Transportation Repairable	S	TSCAB(13) 0.0	TSCAT(13) 1000.0
X(J1,14)	Average Total Cost	T	TSCAB(14) 0.0	TSCAT(14) 4000.0
X(J1,15)	Average Investment Level	U	TSCAB(15) 0.0	TSCAT(15) 0.0

Note:

1. Left scale of Plot will use minimum and maximum input values of any of the above if input parameter (N9) is set equal to array location (In this example N9 = 10)

2. Right scale of Plot will use minimum and maximum input values of any of the above if input parameter (N10) is set equal to array location (In this example N10 = 14)

TABLE IX


*** COST DATA ***
840,000
830,000
820,000
810,000
800,000
790,000
780,000
770,000
760,000
750,000
2050.0
2045.0
2040.0
2035.0
2030.0
2025.0
2020.0
2015.0
2010.0
2005.0
0
10
20
30
40
50
60
70
80
90
100
PERIODS

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A dynamic Monte Carlo simulation of a re
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